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When Should a Firm Expand Its Business?

The Signaling Implications of Business Expansion[*]

Ana Espínola-Arredondo[†] Esther Gal-Or[‡] Félix Muñoz-García[§]

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Abstract

We examine an incumbent's trade-off between the improved efficiency that business expansion facilitates and the signaling role that business expansion plays in conveying information to potential entrants about the state of demand. We demonstrate that both separating and pooling equilibria survive the Intuitive Criterion. Essentially, in contrast to models with asymmetric information about unit cost, incumbents' benefits from investing in a signal are not necessarily monotonic in the state of demand. We investigate how the extent of informativeness of the outcome depends on the enhanced efficiency that the incumbent's expansion facilitates and the priors of the entrant.

Keywords: Business expansion; Signaling; Entry deterrence; Failure rates.
JEL Classification: L12, D82.

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1 Introduction

Firms regularly have to make decisions about expanding their businesses by acquiring new technologies, enlarging the size of their plant or hiring more workers. This expansion may have a direct effect on the firms' profits by reducing costs or by facilitating serving a larger group of customers. However, it may also have an indirect effect, because of the role it plays in signaling market conditions to potential competitors. In this article we investigate the trade-offs introduced by these two effects. We explore the signaling role that expansion plays in communicating market demand to potential entrants, and how an incumbent's expansion decision is affected by the potential entry of competitors.

Our model is especially relevant in growing markets, where potential entrants have very little information about the state of the demand. This is valid in particular in markets that have been monopolized for a while, thus making it difficult for new companies to assess the prospects of entering the market. The potential investors, in this case, watch carefully actions taken by the incumbent in attempting to evaluate market conditions. The expansion decision of the incumbent is one such action.

Given our objective in this article, we examine a signaling model where the incumbent privately observes the actual realization of market demand (either high or low) and decides whether to expand her business. The expansion is observed by the entrant who uses it as a signal to infer the true state of demand. After updating his beliefs of market demand the entrant decides whether to enter the market. Specifically, we investigate whether the expansion decision of the incumbent can transmit valuable information to the entrant about the state of the demand.

We find two types of pure strategy pooling equilibria that support entry. They can arise in our model contingent upon the level of cost that the incumbent has to incur in order to expand her business and the prior expectation of the entrant. First, if expansion costs are relatively low and if the entrant is very optimistic about the likelihood that demand is high, the incumbent expands her business irrespective of the state of demand and the entrant invests in the market. In contrast, when expansion costs are relatively high and the priors of the entrant are moderately optimistic, the incumbent never expands her business, and the entrant enters the market nevertheless. In addition, we demonstrate that both types of pooling equilibria satisfy the Intuitive Criterion in our model. Essentially, in contrast to models with asymmetric information about unit cost, incomplete information about the demand does not necessarily imply that the incumbent facing high demand derives greater benefits from investing in a signal than an incumbent facing low demand. This in spite of the fact that a high demand incumbent can probably finance its expansion for a lower cost than a low demand incumbent given that it may have resources to self finance a bigger portion of the investment. As the Single Crossing Property does not necessarily hold, pooling equilibria survive equilibrium refinements.

The first type of equilibrium with entry explains patterns of expansion of firms operating in markets with overall strong levels of demand. In certain markets even the most pessimistic estimates of the demand are still sufficiently strong to support expansion of current businesses, even when they anticipate additional entry of new competitors. This is the case, for instance, for some electronic markets, such as the MP3 players. Growth expectations of this market in 2008 varied significantly, with International Data Corporation predicting a growth rate of 75% per year until 2009 (Newratings.com), and other sources being less optimistic and predicting a growth rate of 10% (see In-Stat.com, a research group focused on communication industries). Both estimates were nevertheless sufficiently strong to support additional entry to the industry at the time. The second type of pooling equilibrium with entry arises when the costs of financing the expansion are relatively high. In this case entry occurs in spite of no indication that favorable demand conditions are in place. This type of equilibrium is supported by some stylized empirical results obtained in the literature of industrial economics, showing that new entrants comprise a significant share of many US industries (about 20% according to Dennis (1997)). New entrants, however, are not only attracted to highly profitable but also to unprofitable markets. For instance, Bernardo and Welch (1997) estimate that 75% of entrants in the U.S. die within their first five years and Mata and Portugal (1994) found a 50% failure rate of Portuguese firms within their first four years. The above empirical results support the second type of pooling equilibrium with entry, where entrants base their entry decision on some preliminary, imprecise information about the demand, without being able to update this information from the business decisions of established companies. In particular, they may choose to invest even when actions taken by the established companies give no indication of favorable prospects in the market.

This pattern of entry has been previously analyzed using arguments different from those we consider in this article. For example, some contributions to the literature have explained this entry phenomenon using arguments related to "network externalities"; namely the expanded customer traffic that is induced by the joint location of companies in the same area.[1] Another explanation was offered by Camerer and Lovallo (1999) who suggest that entrants may decide to enter (even unprofitable) markets because they are overly confident of their abilities.[2] Our article provides an explanation that does not rely on behavioral reasons. It is simply the result of lack of information on the part of potential investors that leads to their entry into sometimes unprofitable markets, and not their overconfidence.

We also identify regions of parameter values for which fully informative separating equilibria can be supported where only an incumbent facing high demand expands her business. In these separating equilibria the entrant infers market conditions from the incumbent's expansion decision, and enters the market only if demand is high. Furthermore, we demonstrate the existence of two types of semi-separating equilibria. In the first type, the incumbent facing high demand expands with probability one and the incumbent facing low demand expands with a positive probability less than one. In the second type of semi-separating equilibrium both incumbents strictly randomize,

[1] Eaton and Lipsey (1979), Stahl (1982) and Wolinsky (1983). For a summary of the main contributions in this literature see Fujita and Thisse (2002).

[2] This entry and exit patterns could alternatively be explained by a model where the entrant is informed about market demand but does not have precise information about its production costs until entering the market, as in Harrington (1986). We elaborate on Harrington's (1986) model below.

with the incumbent facing high demand still choosing expansion with higher probability. In both types of equilibria, the expansion decision of the incumbent delivers favorable information about market demand to the entrant. Because at the semi-separating equilibrium the probability of expansion is higher for an incumbent facing more favorable demand conditions, expansion implies a higher likelihood that demand is high, thus facilitating a more sensible investment decision for the entrant. In fact, the bigger the difference between the probabilities of expansion of the high and low demand types of incumbents, the more valuable the information that is disseminated by expansion. We demonstrate that this difference in probabilities depends upon the parameters of the model such as the prior probability that demand is high, and the extent of technological improvement that the expansion facilitates. In particular, a more significant technological improvement leads to a semi-separating equilibrium that is more informative from the perspective of the entrant. In fact, if the expansion does not introduce any improvement, which in our model is measured by a reduction in the incumbent's unit cost, neither fully nor semi-separating equilibria can exist, thus leaving the entrant in the dark regarding his prospects in the market.

This result is supported by the literature explaining failure rates in industries experiencing substantial technological improvements. In particular, Jensen et al. (2008) show that survival rates for entrants in industries benefiting from technological improvements are significantly higher than those in industries which do not benefit from technological improvements. In our model as well, significant technological improvements facilitate greater transmission of information about market demand to potential entrants, thus allowing them to make better informed investment decisions.[3] We also show that in order to support the semi-separating equilibrium with both firms strictly randomizing, the financing cost of expansion should be comparable for both types of incumbents.

Finally, we investigate how the prior expectations of the entrant affect the extent of information that is transmitted to the entrant at the equilibrium. We find that the size of the region supporting pure strategy separating equilibria is independent of the entrant's prior expectations. In contrast, semi-separating equilibria can exist only if the entrant is not overly optimistic. Moreover, when the entrant is very pessimistic, only type-1 of the semi-separating equilibria can exist. Between the two types, type-1 is the most informative, given that the high demand incumbent definitely expands and it is only the low demand incumbent who randomizes her expansion decision. Hence, extreme pessimism on the part of the entrant breeds more information transmission at the semi-separating equilibrium. We also show that more information about market demand is likely to be transmitted to the entrant if incumbents operating in high demand markets face lower expansion costs than those producing in low demand markets. In our model such a gap in expansion costs leads to increased likelihood of both separating and semi-separating equilibria.

Building on the seminal work of Spence (1973), the literature on signaling has addressed a wide array of economic situations related to: dividend policy, Kose and Williams (1985), signaling of

[3]JJensen et al.'s (2008) results are applicable to innovations benefiting an entire industry, rather than being firm-specific. Even though our model relates to firm specific innovations, it may still be compatible with the environment considered in Jensen et al., given that entrants into new markets tend to be ignorant about the precise state of market demand.

product quality in markets, Milgrom and Roberts (1986) and Daughety and Reinganum (2007), and signaling among litigants, Reinganum and Wilde (1986) and Daughety and Reinganum (2002), to mention just a few examples. Our article develops such a model in the context of an entry deterrence game, similar to that considered by Milgrom and Roberts (1982). However, whereas in Milgrom and Roberts the entrant is uncertain about the incumbent's cost, in our model he is uncertain about market demand and uses the expansion decision of the incumbent to draw inferences about it. As increasing production during the pre-entry period is more costly for high-cost than for low-cost incumbents, Milgrom and Roberts find separating equilibria in which only low-cost firms reduce prices (use limit pricing to deter entry) during the pre-entry period. Moreover, in Milgrom and Roberts entrants prefer to enter markets with high-cost incumbents, whereas incumbents prefer to be low-cost. In contrast, in our model both incumbents and entrants prefer to operate in high-demand markets, which limits the potential for separating equilibria to arise.[4]

Harrington (1986) modifies Milgrom and Roberts' (1982) model by allowing for the possibility that the entrant is uncertain about his own costs after entry. Interestingly, this article shows that when the costs of the entrant and the incumbent are sufficiently positively correlated then Milgrom and Roberts' (1982) results are reversed. That is, the incumbent's production is below the simple monopoly output in order to strategically deter entry. The intuition is that this low production now conveys information not only of the incumbent's but also of the entrant's costs. As the potential entrant is uncertain of his costs and these costs are highly correlated with those of the incumbent, he infers that his costs are high, thus deterring him from entering the market. Our model is different from Harrington (1986) because in our setting both firms know each other's costs, but the entrant is uninformed about market demand.

Another related article which is probably closest in spirit to ours is Matthews and Mirman (1983). This article analyzes a signaling model where the incumbent sets prices that can communicate some information about market profitability to potential entrants (as in our model). However, the actual price in the market (which is also the message observed by the potential entrant) receives a random shock, given that the incumbent sets its price before demand is actually realized. In contrast, in our model demand is assumed to be perfectly known by the incumbent across periods. Bagwell and Ramey (1990) and Albaek and Overgaard (1994) examine entry deterrence in a model where the potential entrant can perfectly observe both the incumbent's pre-entry pricing strategy and its advertising expenditures. In contrast, we restrict the amount of information available to the entrant to the expansion decision of the incumbent. Finally, in a recent article Ridley (2008) analyzes an environment where an informed firm's entry provides a noisy signal about market demand to additional entrants. Such an informational context is similar to ours, but we assume that the expansion decision of the informed firm may have a favorable effect on her technology, whereas Ridley (2008) assumes that the cost structure is fixed. In fact, informative equilibria can arise in our model only if expansion introduces some technological benefits in addition to serving as a signal

[4] Fudenberg and Tirole (1986) analyze how players may want to use "signal jamming" when choosing actions that can transmit information to a potential entrant. They assume, however, that the incumbent's characteristics are common knowledge, unlike our model where the incumbent privately observes the state of demand.

of high demand.

The article is organized as follows. In the next section, we describe the signaling model, as well as the firms' incentives under each market condition. In Section 3 we analyze the set of pure strategy equilibria and in section 4 we discuss the set of semi-separating equilibria. In section 5 we conclude and offer some extensions of the model. The Appendix includes the proofs of all lemmas and propositions.

2 Model

Let us consider a monopolist (female) who operates as the incumbent in a market. This incumbent privately observes the current level of market demand, either high or low; with inverse demand function given, respectively, as $p(Q) = a_H - bQ$ or $p(Q) = a_L - bQ$, with $a_H > a_L$. An entrant (male) considers whether to enter this market (despite not directly observing the realization of market demand) or to operate in an alternative market where demand is fully observable and given by $(a - bQ)$ and where an existing incumbent operates. Competition in *both* markets is à la Cournot.[5] Both firms' average and marginal costs of production are $c > 0$, except when stated otherwise. The time structure of this incomplete information game is described as follows.

1. Nature decides the realization of market demand, either a_H or a_L with probabilities p and $1 - p$, respectively. This realization is observed by the incumbent, but not by the entrant.
2. Observing the actual level of demand, the incumbent decides whether to expand her business.
3. Observing the incumbent's expansion (or no expansion) decision, the entrant forms beliefs about the level of market demand. Let $\mu(H|E)$ and $\mu(H|NE)$ denote the entrant's posterior beliefs about a high level of demand after he observes, respectively, an expansion or no expansion of the incumbent's business.
4. Given these beliefs, the entrant chooses whether to enter the incumbent's market or an alternative market in which demand is perfectly observed by the entrant.

We assume that expansion is costly and designate by C_H and C_L the expansion cost of the incumbent when demand is high and low, respectively. Moreover, we assume that $C_H \leq C_L$. This assumption reflects the possibility that an incumbent operating in a high-demand market can self-finance a larger portion of the expansion than a low-demand incumbent, thus not having to access capital markets to the same extent..

As a result of expanding her business, the incumbent can reduce her unit cost of production. Specifically, we assume that when the incumbent does not expand her business, both firms' average

[5] Considering a general payoff $\bar{\pi}$ for the entrant from operating in this alternative market (which allows for any form of market structure) would not change the direction of our results, as long as the entrant prefers to enter the incumbent's market when demand is high, and the alternative market when demand is low.

and marginal costs, c, coincide. When the incumbent decides to expand her business, however, her per-unit cost decreases from c to c_1. In contrast, the entrant cannot benefit by acquiring the new technology, as he lacks the incumbent's experience in the industry. Note that when the entrant does not enter the incumbent's market, the latter's monopoly profit in case of a high-demand market is $\frac{(a_H-c)^2}{4b}$ when she does *not* incur the cost-reducing expansion and changes to $\frac{(a_H-c_1)^2}{4b} - C_H$ when she does expand her business. Similar expressions can be obtained for the case of a low-demand market. On the other hand, when the entrant enters the incumbent's market, the firms compete as Cournot duopolists. In the absence of expansion, the profits for both the incumbent and the entrant are $\frac{(a_H-c)^2}{9b}$. However, if the incumbent expands her business, the firms compete with *different* costs. In this case, the profits for the incumbent are $\frac{(a_H-2c_1+c)^2}{9b} - C_H$, and those of the entrant are $\frac{(a_H-2c+c_1)^2}{9b}$ when demand is high, and similar expressions can be derived in the case of a low-demand market.

After observing the expansion decision of the incumbent, we assume that the entrant wants to enter when demand is high, $\frac{(a_H-2c+c_1)^2}{9b} > \frac{(a-c)^2}{9b} > 0$, i.e., $a_H > a+c-c_1$, but prefers to operate in the alternative market when demand is low,[6] $\frac{(a_L-2c+c_1)^2}{9b} < \frac{(a-c)^2}{9b}$, i.e., $a_L < a+c-c_1$. Similarly, when the incumbent does not expand her business, the entrant wishes to enter when demand is high, $\frac{(a_H-c)^2}{9b} > \frac{(a-c)^2}{9b}$, because $a_H > a$, but prefers to operate in the alternative market when demand is low, $\frac{(a_L-c)^2}{9b} < \frac{(a-c)^2}{9b}$, as $a_L < a$. Finally, in the case of entry, the entrant observes market demand and chooses his optimal output. With the incumbent's expansion, this level of output is positive only if $\frac{a_K-2c+c_1}{3b} > 0$, which is valid even when demand is low if $a_L > 2c - c_1$, an assumption we make throughout the article (Hence, entry reduces the incumbent's market share irrespective of the state of the demand).

The incumbent's cost-reducing benefits from expanding her business in the absence of any entry threat can be expressed as follows

$$B_K^{CR} = \frac{(a_K - c_1)^2}{4b} - \frac{(a_K - c)^2}{4b} \quad \text{for all } K = \{H, L\}, \tag{1}$$

where the superscript CR denotes cost-reducing benefits. B_K^{CR} is positive for all parameter values, and converges to zero when $c_1 \to c$, i.e., when the incumbents' marginal costs before and after the expansion coincide. In the absence of entry threats, expansion is worthwhile for both types of incumbents if $B_K^{CR} \geq C_K$ for all $K = \{H, L\}$. If, instead, $B_H^{CR} \geq C_H$ but $B_L^{CR} < C_L$, expansion is only profitable for the incumbent facing high demand. Finally, if $B_K^{CR} < C_K$ holds for all $K = \{H, L\}$, expansion is *not* worthwhile for any type of incumbent. In the next section we investigate how the incentives for expansion change when the incumbent faces the threat of entry.

[6] Note a distinction with entry-deterrence games, such as Milgrom and Roberts (1982), where the incumbent's profits *decrease* in her unit costs, but the entrant's profits *increase* in the incumbent's costs. In contrast, in our paper *both* firms' profits increase with the private information concerning the state of market demand.

3 Equilibrium analysis

Recall that there are two possible effects of the expansion decision of the incumbent. The direct effect is to reduce the incumbent's unit cost and the indirect effect is to determine the extent of information about market demand that is available to the entrant, and as a result, his entry decision. The incumbent's benefit from expanding her business when such expansion induces entry can therefore be represented as follows.

$$B_K^E = B_K^{CR} - \left[\frac{(a_K - c_1)^2}{4b} - \frac{(a_K - 2c_1 + c)^2}{9b}\right], \tag{2}$$

where $K = \{H, L\}$, and the superscript E denotes an expansion that causes *entry*. Note that the incumbent's net benefit from expansion, B_K^E, is the difference between the technological benefit of the expansion, B_K^{CR}, and the loss in profits due to competition (measured for a given cost structure), i.e., $B_K^E < B_K^{CR}$.[7] On the other hand, if expansion deters entry, the incumbent's benefit from expansion can be described as follows:

$$B_K^{ED} = B_K^{CR} + \left[\frac{(a_K - c)^2}{4b} - \frac{(a_K - c)^2}{9b}\right], \tag{3}$$

where $K = \{H, L\}$, and the superscript ED denotes that expansion has *entry deterrence* effects. The incumbent's benefits from expanding her business can be divided again into two components: first, the incumbent experiences a cost-reduction effect arising from her expansion decision, and second, she protects her market from entry.[8] Note that B_K^{ED} exceeds B_K^{CR} for both high and low demand, and for all parameter values. Indeed, when the incumbent deters entry, the benefits from her expansion, B_K^{ED}, are not only technological (reducing her marginal costs from c to c_1, captured by B_K^{CR}) but also strategic, as she retains a larger market share by deterring entry.

Lemma 1. *In the expansion signaling game:*

1. *The benefits from expansion when the incumbent achieves entry deterrence are higher than when she does not achieve deterrence, for every state of demand, i.e.,* $B_K^{ED} > B_K^E$ *for all* $K = \{H, L\}$.

2. *The incumbent's benefits from expanding her business are increasing in market demand when the expansion deters entry, i.e.,* $B_H^{ED} > B_L^{ED} > 0$ *for all parameter values.*

3. *When expansion does not deter entry, the incumbent's benefit from expanding her business is not necessarily an increasing function of the state of demand. Specifically,* $B_H^E \geq B_L^E$ *if and only if* $a_H + a_L \leq \frac{26c - 16c_1}{5}$.

[7] In addition, note that B_K^E can be negative if the cost-reduction effect, B_K^{CR}, is sufficiently small. That is, when the reduction of profits of the incumbent due to entry is larger than the cost-reduction effect she experiences from her expansion, then the benefits from such an expansion, B_K^E, are clearly negative.

[8] Unlike B_K^E, B_K^{ED} is positive for all parameter values.

Hence, when expansion deters entry, the high demand incumbent faces a stronger incentive to expand her business than the low demand incumbent does, $B_H^{ED} > B_L^{ED}$. When expansion does not deter entry, however, this result does not necessarily hold.[9] Before analyzing the set of Perfect Bayesian Equilibria (PBE) of this signaling game, let us introduce some additional notation. In particular, let p^I denote the probability that makes an entrant indifferent between the expected profits from Cournot competition with identical costs, $p\frac{(a_H-c)^2}{9b} + (1-p)\frac{(a_L-c)^2}{9b}$, and the profits from operating in the alternative market, $\frac{(a-c)^2}{9b}$; where the superscript I represents the Cournot market in which both the incumbent and entrant compete with *identical* cost structures. Similarly, the probability that makes an entrant indifferent between the expected profits from Cournot competition in which the incumbent has reduced costs, $p\frac{(a_H-2c+c_1)^2}{9b} + (1-p)\frac{(a_L-2c+c_1)^2}{9b}$, and the profits from operating in the alternative market, $\frac{(a-c)^2}{9b}$, is denoted by p^D, where the superscript D represents the Cournot market in which the incumbent and entrant compete with *different* cost structures.[10] Let us now analyze the set of pure strategy equilibria in this signaling game with cost-reducing expansions. Given that the characterization of the equilibria depends on the probability that demand is high, p, we distinguish among three regimes: low prior probability ($p < p^I$), intermediate prior probability ($p^I \leq p < p^D$), and high prior probability ($p^D \leq p$). Let us first investigate the first regime.

Proposition 1. *When $p < p^I$, the following pure strategy PBE can be supported in the expansion signaling game:*

1. *A separating equilibrium where the incumbent chooses (E_H, NE_L), and the strategy of the entrant is (In_E, Out_{NE}) if and only if $C_H \leq B_H^E$, $C_L > B_L^E$, the entrant's beliefs are $\mu(H|E) = 1$ and $\mu(H|NE) = 0$.*

2. *A pooling equilibrium with no expansion, (NE_H, NE_L), followed by no entry (since $\mu(H|NE) = p < p^I$) if and only if either of the following two cases arises:*

   (a) *the entrant's out-of-equilibrium beliefs are $\mu(H|E) \geq p^D$, expansion costs satisfy $C_K > B_K^E$ for both types of incumbents and the entrant's strategy is (In_E, Out_{NE}); or*

   (b) *the entrant's out-of-equilibrium beliefs are $\mu(H|E) < p^D$, expansion costs satisfy $C_K > B_K^{CR}$ for both types of incumbents and the entrant's strategy is (Out_E, Out_{NE}).*

3. *A pooling equilibrium with expansion, (E_H, E_L), followed by no entry, (since $\mu(H|E) = p < p^D$) if and only if either of the following two cases arises:*

[9] Note that it does not hold when $a_H + a_L > \frac{26c-16c_1}{5}$, i.e., when the cost-reducing effects of the expansion are small, relative to market demand. This implies that the Single-Crossing Property is not satisfied for all parameter values. As a consequence, separating equilibria may not exist. A similar argument would also be valid if the state of demand were drawn from a continuum of possible levels and not only two states and if the incumbent were allowed to choose from a continuum of expansion investments. In general, when expansion is followed by entry, the incumbent operating in a higher demand market does not necessarily obtain a larger benefit from marginally increasing its investment in comparison to an incumbent operating in a lower demand market.

[10] The expression for p^I and p^D are obtained by solving for p in these indifference conditions, where $p^I < p^D$. They are both included in the appendix.

(a) *the entrant's out-of-equilibrium beliefs are* $\mu(H|NE) \geq p^I$*, expansion costs satisfy* $C_K \leq B_K^{ED}$ *for both types of incumbents and the entrant's strategy is* (Out_E, In_{NE})*; or*

(b) *the entrant's out-of-equilibrium beliefs are* $\mu(H|NE) < p^I$*, expansion costs satisfy* $C_K \leq B_K^{CR}$ *for both types of incumbents and the entrant's strategy is* (Out_E, Out_{NE})*.*

In figure 1 we characterize the set of (C_L, C_H) pairs supporting the separating equilibrium and the pooling equilibria in parts 2(a) and 3(a) of Proposition 1.[11] In particular, figure 1a depicts the case where $B_H^E \geq B_L^E$, and thus expansion results in significant technological improvements, whereas figure 1b represents the case in which $B_H^E < B_L^E$. First, note that in the separating equilibrium (E_H, NE_L) the entrant considers that any expansion must *only* come from a high-demand incumbent, which leads him to enter. In contrast, when the entrant does not observe any expansion, he assigns probability one to the low-demand market, and does not enter such a market. Given these incentives of the entrant, the incumbent decides to expand her business when demand is high if and only if her expansion costs, C_H, are sufficiently low, $C_H \leq B_H^E$. In this case the expansion has no entry-deterrence effects (because it attracts potential entrants), but only cost-reduction effects. Hence, the condition $C_H \leq B_H^E$ specifies that the incumbent expands when the costs from expanding her business are lower than the cost-reducing benefit arising from expansion followed by entry. The opposite intuition is applicable for the incumbent operating in a low-demand market (i.e., $C_L > B_L^E$).

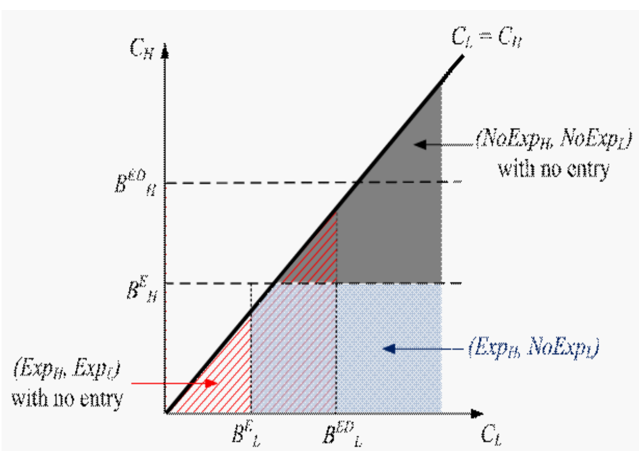

Figure 1a: $B_H^E \geq B_L^E$.

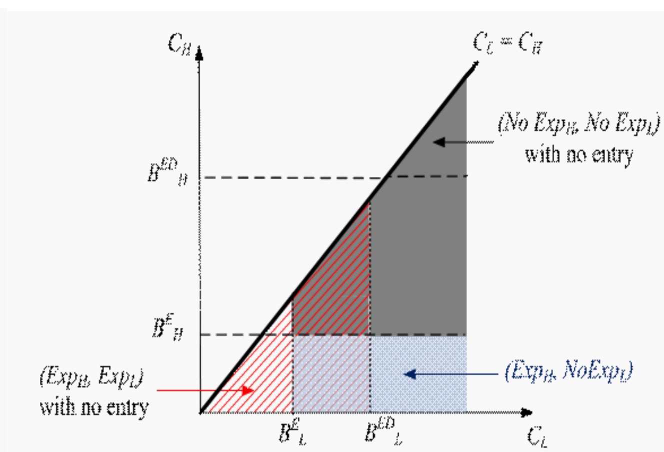

Figure 1b: $B_H^E < B_L^E$.

Note that the separating equilibrium is more likely the bigger B_H^E is and the smaller B_L^E is. In particular, when expansion results in significant technological improvements so that $a_H + a_L \leq$

[11] Figures representing the other combinations of the pooling equilibria described in Proposition 1 can be done in a similar way.

$\frac{26c-16c_1}{5}$ and thus $B_H^E \geq B_L^E$ (figure 1a), full separation can be observed *both* when incumbents face different expansion costs and thus $C_H < C_L$ (the region directly below the main diagonal), *and* when they do not, $C_H = C_L$ (along the main diagonal). Intuitively, information can be perfectly transmitted to entrants if technological improvements are sufficiently strong, regardless of whether there is a gap in the expansion costs facing high and low demand incumbents. In contrast, if technological improvements are relatively small $B_H^E < B_L^E$ (depicted in figure 1b), the area of expansion costs supporting full separation lies strictly below the diagonal $C_H = C_L$. Under this condition, full separation can only be observed when the expansion cost facing the low demand incumbent is sufficiently higher than that facing the high demand incumbent.

The second equilibrium we describe in figure 1 is the pooling equilibrium in which no type of incumbent expands her business, (NE_H, NE_L). In this equilibrium, entry does not occur because the prior probability of high demand is relatively low, $p < p^I$, and expansion costs are moderately high, $C_K > B_K^E$, inducing the incumbent to not expand. Finally, in the third type of equilibrium, both types of incumbents expand their business, (E_H, E_L), given that expansion costs are moderately low, $C_K \leq B_K^{ED}$. Because, in addition, priors are relatively pessimistic, $p < p^I$, the entrant stays out of the market. Both types of pooling equilibria are supported by appropriately specifying the out-of-equilibrium beliefs of the entrant when observing expansion or no expansion, respectively. It is noteworthy that figure 1 indicates the coexistence of multiple equilibria in some regions. In particular, when $C_L \in (B_L^E, B_L^{ED})$ and $C_H \leq B_H^E$ the separating equilibrium coexists with the pooling equilibrium with expansion. In Proposition 2 we investigate the second regime where the prior probability of high demand, p, falls in the intermediate range $p^I \leq p < p^D$.

Proposition 2. *When $p^I \leq p < p^D$, the equilibria 1 and 3 from Proposition 1 can be supported under the same parameter values. In contrast, the pooling equilibrium of no expansion, (NE_H, NE_L), can be supported with entry (since $\mu(H|NE) = p \geq p^I$) if and only if either of the following two cases arises:*

1. *the entrant's out-of-equilibrium beliefs are $\mu(H|NE) < p^D$, expansion costs satisfy $C_K > B_K^{ED}$ for both types of incumbents and the entrant's strategy is (Out_E, In_{NE}); or*
2. *the entrant's out-of-equilibrium beliefs are $\mu(H|NE) \geq p^D$, expansion costs satisfy $C_K > B_K^O$ for both types of incumbents and the entrant's strategy is (In_E, In_{NE}), where $B_K^O \equiv (B_K^{ED} - B_K^{CR}) + B_K^E$.*

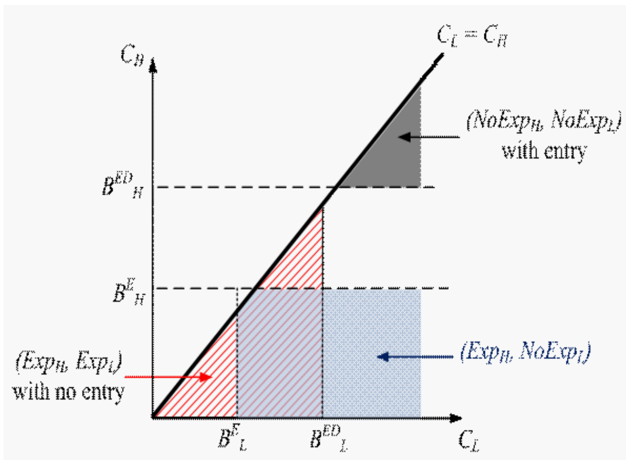

Figure 2a: $B_H^E \geq B_L^E$.

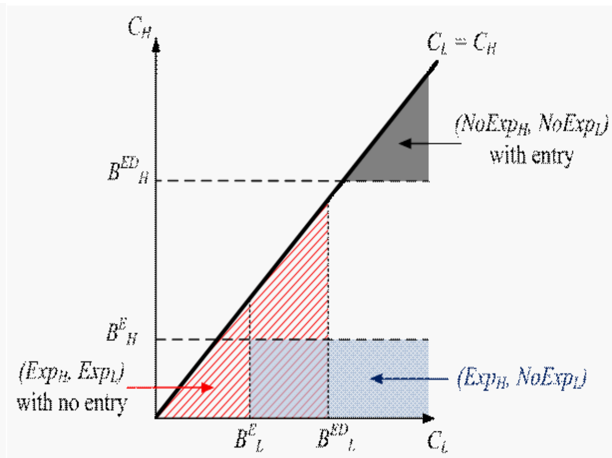

Figure 2b: $B_H^E < B_L^E$.

Figures 2a and 2b illustrate the set of expansion costs supporting each of these equilibria in pure strategies, for $B_H^E \geq B_L^E$ and $B_H^E < B_L^E$, respectively, where for simplicity, we focus on the pooling equilibrium of only part 3(a) from Proposition 1 and part 1 from Proposition 2.

Note that the intuition for both the separating equilibria and for the pooling equilibrium in which both types of incumbents expand their business from figures 1a and 1b is also applicable to figures 2a and 2b. In contrast, the characterization of the pooling equilibrium when both types of incumbents do *not* expand their business is different from that of figures 1a and 1b. In particular, whereas in figure 1 the prior probability of high demand is very low ($p < p^I$), and therefore the potential for entry deterrence is relatively high, in figure 2 the prospects of high demand are better ($p \geq p^I$) and deterring entry is more difficult. As a result, the incumbent is more inclined to expand in figure 2 than in figure 1 in order to benefit from the efficiency improvement that expansion supports. Only if expansion costs are very high ($C_K > B_K^{ED}$), the incumbent chooses not to expand, whereas the entrant enters the market nevertheless as he is relatively optimistic. This equilibrium can rationalize the observation that, due to high financing costs, small firms may decide not to expand their businesses; and in spite of this "negative" news transmitted to the entrant, additional firms join the market.[12] Note that, similarly to figure 1, figure 2 shows the coexistence of equilibria arising when $C_L \in (B_L^E, B_L^{ED})$ and $C_H \leq B_H^E$ (the separating equilibrium coexists with the pooling equilibrium with expansion). Let us finally examine the third regime, where the prior probability of high demand, p, is sufficiently high, $p \geq p^D$.

[12] Indeed, examples abound of new entrants investing despite of no expansion by existing businesses in the area. The literature has suggested the existence of network externalities to explain such entry decisions. This paper provides an additional argument to explain entry into such "crowded" markets, even in the absence of network externalities.

Proposition 3. *When $p \geq p^D$, the separating equilibrium from Proposition 1, and the pooling equilibria with no expansion and entry from Proposition 2, can be supported as pure strategy PBE of the signaling game. In contrast, the pooling equilibrium with expansion, (E_H, E_L), can be supported with entry (since $\mu(H|E) = p \geq p^D$) if and only if either of the two following cases arises:*

1. *the entrant's out-of-equilibrium beliefs are $\mu(H|E) < p^I$, expansion costs satisfy $C_K \leq B_K^E$ for both types of incumbents and the entrant's strategy is (In_E, Out_{NE}); or*
2. *the entrant's out-of-equilibrium beliefs are $\mu(H|E) \geq p^I$, expansion costs satisfy $C_K \leq B_K^O$ for both types of incumbents and the entrant's strategy is (In_E, In_{NE}).*

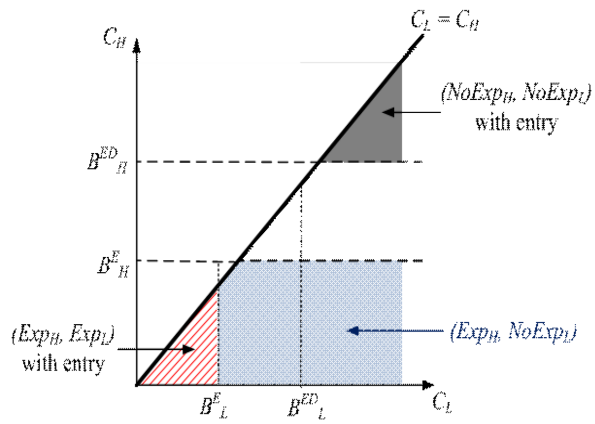

Figure 3a: $B_H^E \geq B_L^E$.

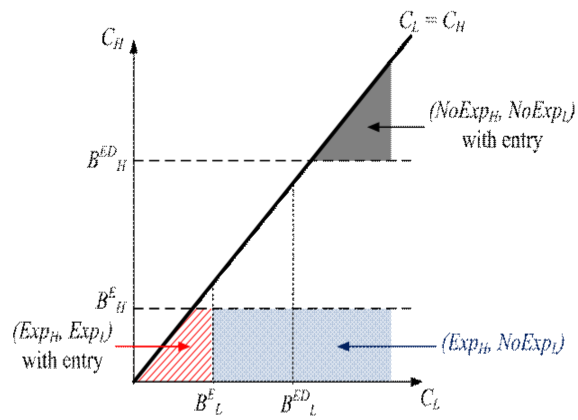

Figure 3b: $B_H^E < B_L^E$.

Figures 3a and 3b represent the set of equilibria described in Proposition 3 where, for simplicity, we depict the pooling equilibria of part 1 from propositions 2 and 3. A comparison of figures 3a and 3b with figures 1 and 2 indicates that more optimistic beliefs reduce the size of the region supporting pooling equilibria. Moreover, at the pooling equilibria the entrant always chooses to enter the market irrespective of whether the equilibria are characterized by expansion or no expansion of the incumbent. In figures 1 and 2, when the entrant is less optimistic, he decides to stay out at the pooling equilibrium characterized by expansion.

In the following lemma we investigate whether the equilibrium derived in Propositions 1-3 survive the Cho and Kreps' (1987) Intuitive Criterion. Both pooling equilibria (with and without expansion) survive the Intuitive Criterion under most parameter conditions. Given that the set of equilibria violating the Intuitive Criterion depends on the incumbents' expansion costs, we distinguish among three cases: (1) both incumbents facing comparably high expansion costs, (2) both facing comparably low expansion costs, and (3) the high-demand incumbent facing significantly lower expansion costs than the low-demand incumbent.

Lemma 2. *All equilibria identified in Propositions 1-3 survive the Cho and Kreps' (1987) Intuitive Criterion, except:*

1. *The pooling equilibria of expansion and no entry (as described in part 3a of Proposition 1) if both types of incumbents face comparably high expansion costs, i.e. if* $C_K \in \left(B_H^{CR}, B_L^{ED}\right)$.
2. *The pooling equilibria of no expansion if both types of incumbents face comparably low expansion costs, i.e., when* $C_K \in \left(B_K^E, B_L^{CR}\right)$ *with no entry (as described in part 2a of Proposition 1), and when* $C_K \in \left(B_K^O, B_L^{ED}\right)$ *with entry (as described in part 2 of Proposition 2).*
3. *The pooling equilibria of expansion if the high-demand incumbent faces significantly lower expansion costs than the low-demand incumbent, i.e., if* $C_L \in \left(B_L^{CR}, B_L^{ED}\right)$ *and* $C_H < B_H^{CR}$ *when expansion is followed by no entry (as described in part 3a of Proposition 1), and* $C_L \in \left(B_L^E, B_L^O\right)$ *and* $C_H < B_H^E$ *when expansion is followed by entry (as described in part 2 of Proposition 3).*

First, note that when *both* types of incumbents face sufficiently low expansion costs (i.e., $C_K < B_K^E$ with entry or $C_K < B_K^{CR}$ with no entry), the pooling equilibrium of expansion survives the Intuitive Criterion. Similarly, when *both* types of incumbents face sufficiently high expansion costs (i.e., $C_K > B_K^{ED}$ with entry or $C_K < B_K^{CR}$ with no entry), the pooling equilibrium of no expansion survives the Intuitive Criterion. Essentially, the incumbent has strong incentives to expand (not to expand) when expansion costs are very low (very high), respectively.

In contrast, when expansion costs are moderate, the pooling equilibria might violate the Intuitive Criterion under certain conditions. First, when both incumbents face moderately high expansion costs, i.e., if $C_K \in \left(B_H^{CR}, B_L^{ED}\right)$, the pooling equilibrium of expansion violates the Intuitive Criterion, as described in part 1 of Lemma 2. Indeed, expansion costs are too high to sustain expansion as a sensible outcome in this case. Second, when both incumbents face moderately low expansion costs, i.e., if $C_K \in \left(B_K^E, B_L^{CR}\right)$ with no entry, and if $C_K \in \left(B_K^O, B_L^{ED}\right)$ with entry, the pooling equilibrium of no expansion violates the Intuitive Criterion, as described in part 2 of Lemma 2. In this case, since expansion costs are sufficiently low, the absence of expansion cannot be sustained as a sensible outcome.

Finally, part 3 of Lemma 2 demonstrates that the pooling equilibrium of expansion violates the Intuitive Criterion if the high-demand incumbent faces significantly lower expansion costs than the low-demand incumbent does. Under the condition stated in part 3, the high-demand incumbent has much stronger incentives to expand than the low-demand incumbent, thus preventing a similar expansion decision by both types of incumbents from satisfying the Intuitive Criterion.

4 Information transmission with Semi-Separating Equilibria

In this section, we examine the existence of equilibria that allow for randomized expansion decisions. We refer to these equilibria as semi-separating because the outcome can potentially transmit valuable information to the entrant if the two types of incumbents randomize with different probabilities. As in the previous section, it turns out that the characterization of the equilibria crucially depends on the prior probability that demand is high. We distinguish, therefore, among the same three regimes: low prior probability $p < p^I$, intermediate $p^I \leq p < p^D$ and high $p^D \leq p$. Proposition 4 investigates the first regime.

Proposition 4. *When $p < p^I$, a unique semi-separating strategy equilibrium can be characterized as follows:*

1. *When demand is high, the incumbent definitely expands her business, $q_H = 1$; and when demand is low, the incumbent expands with probability $q_L \in (0,1)$, where*

$$q_L = \frac{p(1-p^D)}{(1-p)p^D} \tag{4}$$

2. *After observing expansion, the entrant enters with probability $r = \frac{B_L^{CR} - C_L}{B_L^{CR} - B_L^E}$; and when observing non-expansion, the entrant does not enter. The entrant's beliefs are $\mu(H|E) = p^D$ and $\mu(H|NE) = 0$. This equilibrium can be supported if $C_H \leq B_L^{CR}$ and $\max\{B_L^E, C_L^2, C_H\} < C_L < B_L^{CR}$, where $C_L^2 = B_L^{CR} - B_H^{CR}F + FC_H$, and $F = \frac{B_L^{CR} - B_L^E}{B_H^{CR} - B_H^E}$.*

Hence, when the likelihood of high demand is relatively low ($p < p^I$), there may exist a semi-separating equilibrium with $q_H = 1$ and $q_L \in (0,1)$, we refer to this semi-separating equilibrium as Type-1. In figure 4 we represent the set of expansion costs that can support such an outcome.

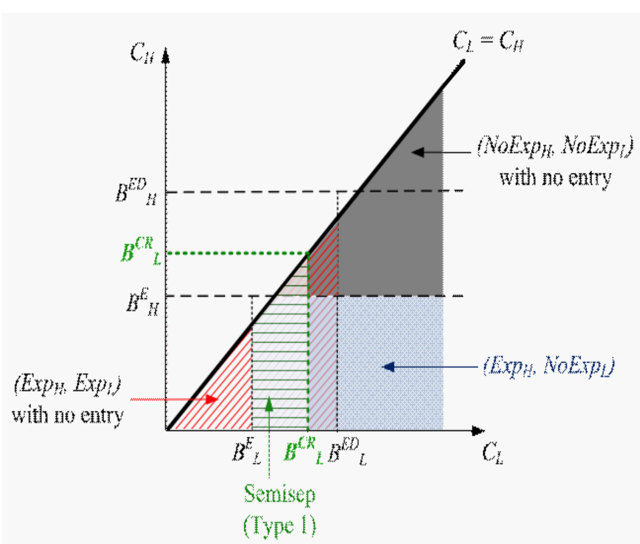

Figure 4a: $B_H^E \geq B_L^E$.

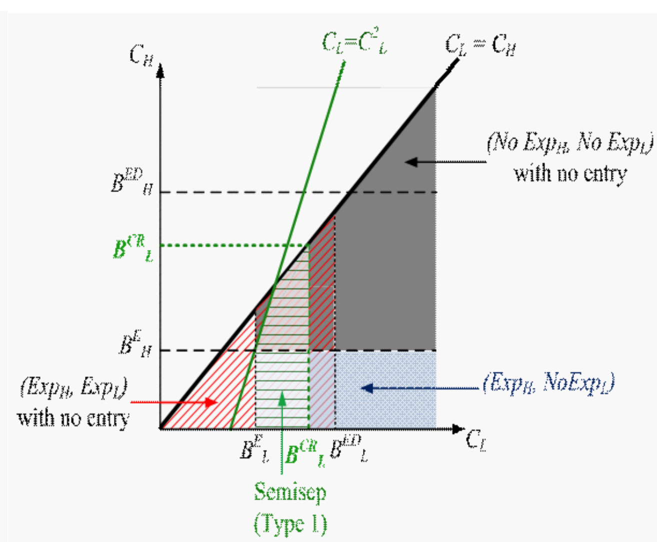

Figure 4b: $B_H^E < B_L^E$.

In figure 4 we distinguish between the case that $B_H^E \geq B_L^E$ and the reverse inequality $B_H^E < B_L^E$. In both cases the feasible region requires that $C_L > B_L^E$. However, in the former case $\max\{C_L^2, C_H\}$ is always C_H, implying that the 45^0-line is the binding lower bound on C_L for all feasible C_H values. In the latter case, either C_H or C_L^2 may be more binding contingent upon the exact value of C_H. It is noteworthy that the region supporting the semi-separating equilibrium concurrently supports also fully separating and pooling equilibria without entry. If $C_H \leq B_H^E$ both fully separating and pooling equilibria coexist with the semi-separating equilibrium, and if $C_H > B_H^E$ only fully pooling equilibria coexist.[13]

Note that q_L, the probability of expansion of an incumbent facing low demand, is a decreasing function of p^D. From the expression derived for p^D it follows, therefore, that the probability of expansion of an incumbent facing low demand is increasing in the parameters p, c_1, a_L and a_H. Whenever either one of these parameters increases, the expected payoff of the entrant rises upon investing in the industry after the incumbent's expansion. Hence, to support the randomizing behavior of the entrant, the incumbent facing low demand has to increase the probability of her expansion, q_L, in order to lower the entrant's expected payoff and maintain his indifference between entry and non-entry. A similar rationale explains also why q_L is a decreasing function of a and an ambiguous function of parameter c.

As far as the probability of entry upon expansion, r, is concerned, its value is determined so as to keep the incumbent facing low demand indifferent between expansion and non-expansion. Hence, a change in any parameter that increases the expected payoff of expansion implies that r increases as well, in order to maintain the incumbent's indifference. In particular, when C_L declines r increases, as lower expansion costs increase profits from expansion, thus requiring that the likelihood of entry increases as well to maintain the randomizing behavior of the low-demand incumbent.

In proposition 5 we investigate the second regime when the prior probability of high demand, p, falls in the intermediate range $p^I \leq p < p^D$.

Proposition 5. *When $p^I \leq p < p^D$, there are two types of semi-separating strategy profiles that can be supported as equilibria of the signaling game:*

(i) *The Type-1 semi-separating equilibrium characterized in Proposition 4; and*

(ii) *The Type-2 semi-separating equilibrium, where the incumbent expands with probabilities $q_H \in (0,1)$ when demand is high and $q_L \in (0,1)$ when demand is low, where*

$$q_H = \frac{p^D(p - p^I)}{p(p^D - p^I)}, \quad \text{and} \quad q_L = \frac{(1 - p^D)(p - p^I)}{(1 - p)(p^D - p^I)}. \tag{5}$$

The entrant enters with probability $r \in (0,1)$ after observing expansion, and with probability $s \in (0,1)$ after observing no expansion (appendix). The entrant's beliefs are $\mu(H|E) = p^D$

[13] This coexistence is applicable to the separating equilibrium and to *all* pooling equilibria of expansion identified in Proposition 1. However, the pooling equilibrium of no expansion described in part 2(a) of Proposition 1 coexists with the semi-separating equilibrium, whereas the pooling equilibrium in 2(b) does not coexist.

and $\mu(H|NE) = p^I$. *This equilibrium can be supported iff* $B_H^E < C_H < \frac{B_L^{CR} - FB_H^{CR}}{(1-F)}$ *and* $\max\{C_H, C_L^1, C_L^3\} < C_L < C_L^2$, *where* $C_L^1 = B_L^{ED} - B_H^{ED}F + FC_H$, F *and* C_L^2 *were defined in Proposition 4, and*

$$C_L^3 = \frac{C_L^2(B_L^{ED} - B_L^{CR} + B_L^E) - C_L^1 B_L^E}{F(B_H^{ED} - B_H^{CR})}. \tag{6}$$

In figure 5 we represent the set of expansion costs that support the two types of semi-separating equilibria characterized in Proposition 5. We distinguish, once again, between the case where $B_H^E \geq B_L^E$ and $B_H^E < B_L^E$. Recall from our earlier observation that the latter inequality holds if the extent of technological improvement induced by the expansion is relatively low (i.e., if $a_H + a_L > \frac{26c - 16c_1}{5}$). It turns out that the second type of semi-separating equilibria of Proposition 5, that has both incumbents randomizing, can exist only if $B_H^E < B_L^E$. If this inequality is reversed, $C_L^3 > C_L^2$ for all relevant expansion costs and the set of expansions costs described in part (ii) of the proposition is empty.

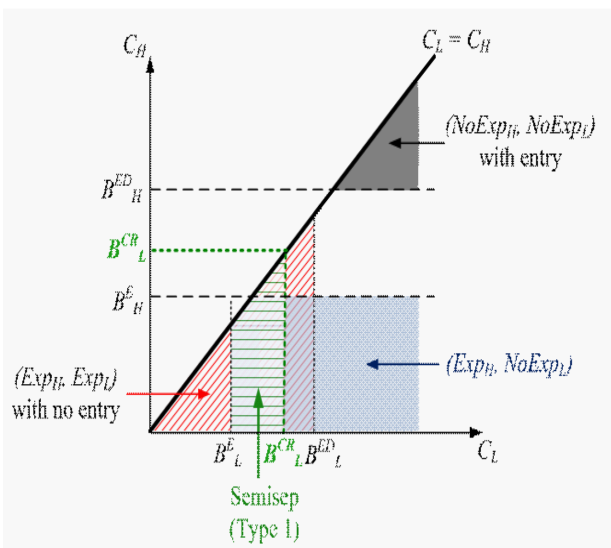

Figure 5a: $B_H^E \geq B_L^E$.

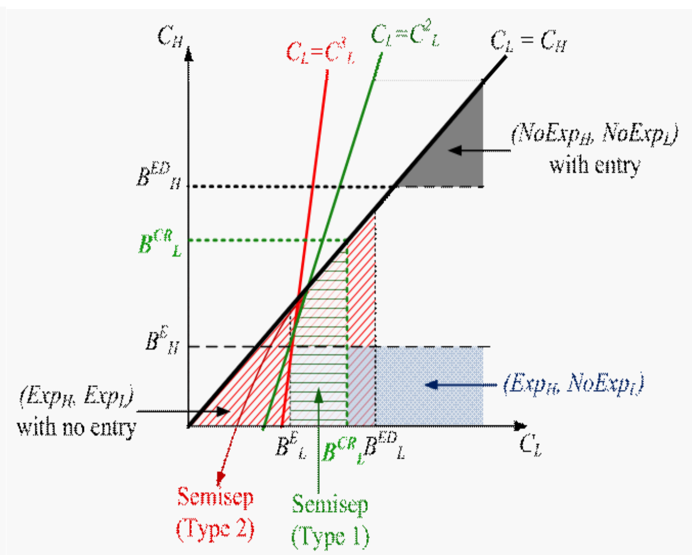

Figure 5b: $B_H^E < B_L^E$.

As can be seen from figure 5b, an equilibrium with both types randomizing (Type-2) can exist only when the discrepancy between the expansion costs ($C_L - C_H$) is relatively moderate (the region supporting this equilibrium lies close to the 45^0-line). To support the equilibrium with only one firm randomizing (Type-1 equilibrium, where $q_H = 1$ and $q_L < 1$), greater discrepancy may be necessary. Note that when both types of firms randomize, $q_H > q_L$ and $r > s$. Hence, the incumbent facing high demand is more likely to expand than the one facing low demand, and as a result, the entrant is more likely to enter upon the incumbent's expansion ($r > s$). Similarly to figure 4, note that the region supporting semi-separating equilibria concurrently supports also fully separating and pooling equilibria without entry.[14]

Assessing how changes in the parameters affect the values of q_H and q_L is difficult given that p^D and p^I are cumbersome expressions of the parameters. For some of the parameters, however, the assessment is relatively simple. For instance, an increase in the value of a that measures the demand intercept in the alternative market, results in higher values of both p^I and p^D. Upon inspection of the expressions derived for q_H and q_L, it follows, therefore, that the probabilities of expansion decline as a increases. As pointed out earlier, the decline balances the incentives of the entrant so that he remains indifferent between entering and staying out of the market.

Finally in Proposition 6 we address the environment with a very high prior probability of high demand.

Proposition 6. *There does not exist any semi-separating equilibrium when $p \geq p^D$.*

According to proposition 6, when the entrant is very optimistic about the prospects of the market, there are no equilibria that support randomizing behavior on the part of the incumbent. Only the strictly separating or strictly pooling equilibria characterized in Proposition 3 can arise in this case. It is interesting to note that semi-separating equilibria arise in our model only in regions where additional pure strategy equilibria also exist. When $p < p^I$, multiple pure strategy equilibria also arise in the region where a semi-separating equilibrium exists, and when $p^I \leq p < p^D$ either multiple or a single additional pure strategy equilibrium exists. Semi-separating equilibria never arise in regions where pure strategy equilibria fail to exist. In particular, when $p \geq p^D$, there is a relatively large region of (C_L, C_H) values that cannot support any pure strategy equilibrium. Semi-separating equilibria do not exist in this region as well. Hence, a very optimistic entrant leads to reduced likelihood that the market can equilibrate. In particular, it eliminates completely the possibility that the incumbent randomizes in her expansion decision.

As was mentioned above, the semi-separating equilibria may coexist with both strictly separating (when $C_H \leq B_H^E$) and pooling equilibria without entry. When the strictly separating equilibrium exists, it obviously generates more accurate information for the entrant than the semi-separating equilibrium does. However, when $C_H > B_H^E$, implying that only pooling equilibria can co-exist with the semi-separating equilibrium, the latter type of equilibrium is more informative than the former. As a result, whereas the pooling equilibrium does not support any entry, the semi-separating equilibrium can support some entry.

It may be interesting to investigate how the parameters of the model affect the extent of informativeness of the semi-separating equilibria. A sensible measure of the extent of informativeness of the equilibrium is the difference $(q_H - q_L)$. A larger discrepancy in the probabilities of expansion by the two types of firms implies that, when expansion is observed, it is far more likely to indicate

[14] This is applicable to *all* pooling equilibria of expansion identified in Proposition 2. However, the pooling equilibrium of no expansion described in part 1 of Proposition 2 never coexists with the semi-separting equilibrium for all parameter values. Similarly, that described in part 2 of Proposition 2 coexists with the semi-separating equilibrium if, in addition, $2B_L^{CR} > B_L^{ED} - B_L^E$, i.e., cost reducing effects are significant.

that demand is indeed high. In figure 6, we depict the extent of informativeness of the two types of semi-separating equilibria.

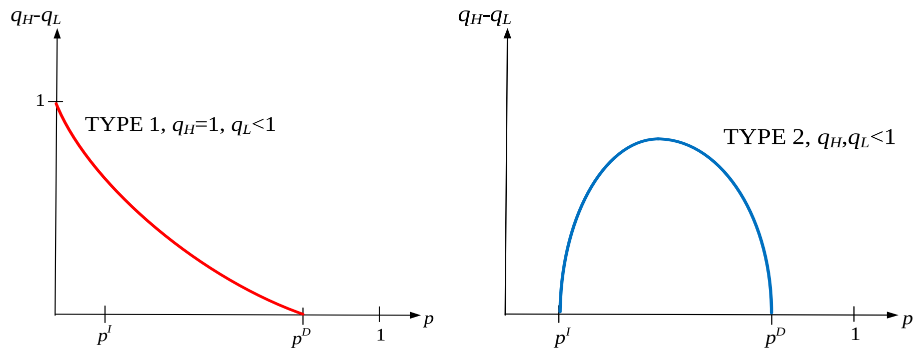

Figure 6: Informativeness of the Semi-Separating equilibria.

According to figure 6, the Type-1 semi-separating equilibria become less informative the more favorable the prior probability p is. In contrast, the extent of informativeness of the Type-2 equilibria is not a monotone function of the prior parameter p. It is an increasing function of p for values of p close to p^I and decreasing for values close to p^D.

It may also be interesting to investigate how the technological implications of the expansion affect the extent of information disseminated at the equilibrium. The technological implication of the expansion is measured by the difference $(c - c_1)$, where a larger difference indicates that the expansion generates more significant technological improvements. Recall from our discussion in the previous section that strictly separating equilibria are more likely to exist the more significant the technological benefits derived from the expansion are. Similarly, our derivations indicate that more significant technological improvements yield also more informative semi-separating equilibria. First, from figure 5 it follows that for sufficiently low values of c_1, indicating significant technological improvement generated by the expansion, only the Type-1 semi-separating equilibria can exist[15]. Hence, significant technological improvements can only support the more informative type of semi-separating equilibria, where the incumbent facing high demand expands with probability one.

Moreover, it is easy to show that the expression for $(1 - q_L)$ in the Type-1 semi-separating equilibrium and the corresponding expression for $q_H - q_L$ in the Type-2 equilibrium are decreasing functions of c_1. Hence, with less significant technological improvements (increase in c_1), the signaling equilibrium becomes less informative. In particular, when $c_1 \to c$, both strictly and semi-separating equilibria fail to exist altogether. In this case $B_H^E < B_L^E < B_L^{CR} = 0$, implying that the regimes supporting any type of separation are empty. In fact, when $c_1 = c$ the only equilibrium that survives is the pooling equilibrium without expansion. We can conclude, therefore, that costly

[15] Note that if c_1 is relatively small $C_L^1 > C_L^2$ for all feasible values of C_H. As a result, the feasible region necessary to support the Type-2 equilibria in figure 5 is empty, because C_L should be in the range (C_L^1, C_L^2) for the Type-2 to exist.

expansion that has no technological implications can never be used as an informative signal about the state of demand. In order to support some separation at the equilibrium, expansion should benefit the incumbent technologically. Because a high demand incumbent benefits from technological improvements to a larger extent than a low demand incumbent, it may have higher incentives to expand. Even though those higher incentives may be insufficient to support pure strategy separating equilibria (if $C_H > B_H^E$), partial separation may arise nevertheless if expansion costs lie in the regions depicted in figures 4 and 5.

5 Concluding remarks

We have considered a model where the expansion decision of an incumbent firm may not only improve its technology but also serve as a signal to potential entrants of favorable demand conditions. We demonstrate that both strictly pooling and strictly separating equilibria survive the Intuitive Criterion as the Single-Crossing Property is violated when both the incumbent and the entrant benefit from favorable demand conditions. The separating equilibrium is more likely to arise the more significant the technological improvements that expansion can support. We also show that semi-separating equilibria can exist and become more informative the more significant the technological improvements are. In essence, given that an incumbent facing high demand benefits from unit cost reduction to a larger extent than an incumbent facing low demand, it may have higher incentives to expand its business. As a result, the expansion decision of the incumbent transmits more valuable information to the entrant.

In addition to signaling equilibria that are either partially or fully informative, we also characterize pooling equilibria with and without entry. To support the non-entry pooling equilibria the entrant has to be relatively pessimistic about the prospects of the demand, and to support entry the opposite must be the case. However, entry may occur even when both types of incumbents choose not to expand their business. Hence, even absent any favorable actions taken by the incumbent, the entrant may decide to enter the market while remaining ignorant about the true state of demand.

Different extensions of this model would enhance its predictive power in more realistic settings. First, note that we assume that incumbents incur fixed expansion costs, thus not allowing for the possibility that a larger investment in cost-reducing technologies induces a more significant decrease in the firm's marginal cost. Introducing a richer set of investment strategies is likely to induce incumbents facing high demand to invest more heavily than incumbents facing low demand, thus facilitating more substantial transmission of information about market demand to entrants (and potentially eliminating pooling equilibria). Second, we assume that the financial market does not observe the state of market demand. However, the incumbent's expansion decision could serve as a signal to transmit information about demand to two audiences: the entrant and financial markets. Clearly, with signaling to two audiences, financial markets would favor firms whose demand is believed to be higher. As we showed in our article, however, high-demand incumbents facing lower expansion costs need not always facilitate information transmission to potential entrants.

6 Appendix

6.1 *Proof of Lemma 1*

We must show that $B_H^{ED} > B_H^E$, so

$$B_H^{ED} - B_H^E = \frac{9(a_H - c_1)^2 + 5(a_H - c)^2 - 4(a_H + c - 2c_1)^2}{36b},$$

which is always positive. In a similar manner, $B_L^{ED} > B_L^E$. Additionally, note that $B_H^{ED} - B_L^{ED} = \frac{(a_H - a_L)[8c + 5(a_H + a_L) - 18c_1]}{36b}$ which is positive for all parameter values. Furthermore, $B_L^{ED} = \frac{9(a_L - c_1)^2 - 4(a_L - c)^2}{36b} > 0$ because $a_L - c_1 > a_L - c$ given that $c_1 \leq c$. Finally,

$$B_H^E - B_L^E = -\frac{(a_H - a_L)\left[5(a_H + a_L) + 16c_1 - 26c\right]}{36b},$$

which is negative if and only if $a_H + a_L > \frac{26c - 16c_1}{5}$. ■

6.2 *Proof of Propositions 1, 2 and 3*

Let us show that the strategy profile $(Exp_H, NoExp_L)$ can be supported as a separating PBE of this signaling game. First, the entrant's beliefs are $\mu = \mu(H|E) = 1$ and $\gamma = \mu(H|NE) = 0$. These beliefs lead him to enter after observing expansion if and only if $\frac{(a_H - 2c + c_1)^2}{9b} > \frac{(a-c)^2}{9b}$, which is true by our assumptions. In contrast, the entrant does not enter after observing no expansion because $\frac{(a_L - c)^2}{9b} < \frac{(a-c)^2}{9b}$ given that $a_L < a$. Given these responses by the entrant, the high-demand incumbent expands if and only if

$$\frac{(a_H - 2c_1 + c)^2}{9b} - C_H \geq \frac{(a_H - c)^2}{4b},$$

which is satisfied if and only if $C_H \leq \frac{(a_H - 2c_1 + c)^2}{9b} - \frac{(a_H - c)^2}{4b} \equiv B_H^E$. On the other hand, the low-demand incumbent does not expand her business if and only if

$$\frac{(a_L - 2c_1 + c)^2}{9b} - C_L < \frac{(a_L - c)^2}{4b},$$

which is satisfied if and only if $C_L > \frac{(a_L - 2c_1 + c)^2}{9b} - \frac{(a_L - c)^2}{4b} \equiv B_L^E$. Hence, this strategy profile can be supported as a separating PBE for expansion costs $C_H \leq B_H^E$ and $C_L > B_L^E$, and beliefs $\mu = 1$ and $\gamma = 0$.

Let us show that the strategy profile $(NoExp_H, Exp_L)$ cannot be supported as a separating PBE of this signaling game. First, the entrant's beliefs are $\mu \equiv \mu(H|E) = 0$ and $\gamma \equiv \mu(H|NE) = 1$. These beliefs lead him to not enter after observing expansion because $\frac{(a_L - 2c + c_1)^2}{9b} < \frac{(a-c)^2}{9b}$, which is true by our assumptions. In contrast, the entrant enters after observing no expansion because $\frac{(a_H - c)^2}{9b} > \frac{(a-c)^2}{9b}$ given that $a_H > a$. Given these responses by the entrant, the high-demand incumbent does not expand if and only if

$$\frac{(a_H - c_1)^2}{4b} - C_H < \frac{(a_H - c)^2}{9b},$$

which is satisfied if and only if $C_H > \frac{9(a_H-c_1)^2-4(a_H-c)^2}{36b} \equiv B_H^{ED}$. On the other hand, the low-demand incumbent expands her business if and only if

$$\frac{(a_L-c_1)^2}{4b} - C_L \geq \frac{(a_L-c)^2}{9b},$$

which is satisfied if and only if $C_L \leq \frac{9(a_L-c_1)^2-4(a_L-c)^2}{36b} \equiv B_L^{ED}$. Hence, this strategy profile could only be supported as a separating PBE when $C_H > B_H^{ED}$, $C_L \leq B_L^{ED}$, and beliefs $\mu = 0$ and $\gamma = 1$, which implies $C_H > C_L$. This contradicts the initial assumption that $C_H \leq C_L$.

Let us now show that the strategy profile $(NoExp_H, NoExp_L)$ can be supported as a pooling PBE of this signaling game. First, the entrant's beliefs are $\gamma \equiv \mu(H|NE) = p$ and $\mu \equiv \mu(H|E) \in [0,1]$. These beliefs lead him to not enter after observing no expansion (in equilibrium) if and only if

$$p\frac{(a_H-c)^2}{9b} + (1-p)\frac{(a_L-c)^2}{9b} < \frac{(a-c)^2}{9b},$$

which is satisfied if and only if $p < \frac{(a-a_L)(a-2c+a_L)}{(a_H-a_L)(a_H+a_L-2c)} \equiv p^I$. Similarly, the entrant enters after observing expansion (off-the-equilibrium path) if and only if

$$\mu\frac{(a_H-2c+c_1)^2}{9b} + (1-\mu)\frac{(a_L-2c+c_1)^2}{9b} \geq \frac{(a-c)^2}{9b},$$

which holds if and only if $\mu \geq \frac{(a+a_L+c_1-3c)(a-c_1-a_L+c)}{(a_H-a_L)(a_H+a_L+2c_1-4c)} \equiv p^D$. Hence, the entrant stays out after observing no expansion (in equilibrium), but enters after observing expansion (out-of-equilibrium). Therefore, the high-demand incumbent does not expand her business if and only if $\frac{(a_H-2c_1+c)^2}{9b} - C_H < \frac{(a_H-c)^2}{4b}$, which implies $C_H > \frac{(a_H-2c_1+c)^2}{9b} - \frac{(a_H-c)^2}{4b} \equiv B_H^E$, and similarly for the low-demand incumbent, she does not expand if and only if $C_L > B_L^E$. Hence, the strategy profile $(NoExp_H, NoExp_L)$ for the incumbent and (In_E, Out_{NE}) for the entrant can be supported as a pooling PBE when $C_K > B_K^E$ and entrant's beliefs are $\mu(H|NE) = p < p^I$ and $\mu(H|E) \geq p^D$, as described in Proposition 1 (part 2a).

- When $\mu(H|NE) = p < p^I$ and $\mu(H|E) < p^D$, the entrant stays out not only after observing no expansion (in equilibrium), but also after observing expansion (out-of-equilbrium). In this case, the high-demand incumbent does not expand her business if and only if $\frac{(a_H-c_1)^2}{4b} - C_H < \frac{(a_H-c)^2}{4b}$, which implies $C_H > \frac{(a_H-c_1)^2}{4b} - \frac{(a_H-c)^2}{4b} \equiv B_H^{CR}$. Similarly for the low-demand incumbent, she does not expand if and only if $C_L > B_L^{CR}$. Hence, the strategy profile $(NoExp_H, NoExp_L)$ for the incumbent and (Out_E, Out_{NE}) for the entrant can be supported as a pooling PBE when $C_K > B_K^{CR}$ and entrant's beliefs are $\mu(H|NE) = p < p^I$ and $\mu(H|E) < p^D$; as described in Proposition 1 (part 2b).

- When $\mu(H|NE) = p \geq p^I$ and $\mu(H|E) < p^D$, the entrant enters after observing no expansion (in equilibrium), but stays out after observing expansion (out-of-equilibrium). In this case, the high-demand incumbent does not expand her business if and only if $\frac{(a_H-c_1)^2}{4b} - C_H < \frac{(a_H-c)^2}{9b}$, which implies $C_H > \frac{(a_H-c_1)^2}{4b} - \frac{(a_H-c)^2}{9b} \equiv B_H^{ED}$. Similarly, the low-demand incumbent does not expand if and only if $C_L > B_L^{ED}$. Hence, the strategy profile $(NoExp_H, NoExp_L)$ for the incumbent and (Out_E, In_{NE}) for the entrant can be supported as a pooling PBE when $C_K > B_K^{ED}$ and entrant's beliefs are $\mu(H|NE) = p \geq p^I$ and $\mu(H|E) < p^D$; as described in Proposition 2 (part 1).

- When $\mu(H|NE) = p \geq p^I$ and $\mu(H|E) \geq p^D$, the entrant enters not only after observing no expansion (in equilibrium), but also after observing expansion (out-of-equilbrium). In this case, the high-demand incumbent does not expand her business if and only if $\frac{(a_H-2c_1+c)^2}{9b} - C_H < \frac{(a_H-c)^2}{9b}$, which implies $C_H > \frac{(a_H-2c_1+c)^2}{9b} - \frac{(a_H-c)^2}{9b} \equiv B_H^O$, where $B_K^O \equiv (B_K^{ED} - B_K^{CR}) + B_K^E$. Similarly for the low-demand incumbent, she does not expand if and only if $C_L > B_L^O$. Hence, the strategy profile $(NoExp_H, NoExp_L)$ for the incumbent and (In_E, In_{NE}) for the entrant can be supported as a pooling PBE when $C_K > B_K^O$ and entrant's beliefs are $\mu(H|NE) = p \geq p^I$ and $\mu(H|E) \geq p^D$; as described in Proposition 2 (part 2).

Let us show that the strategy profile (Exp_H, Exp_L) can be supported as a pooling PBE of this signaling game. First, the entrant beliefs are $\mu \equiv \mu(H|E) = p$ and $\gamma \equiv \mu(H|NE) \in [0,1]$. These beliefs lead him to not enter after observing expansion (in equilibrium) if and only if

$$p\frac{(a_H - 2c + c_1)^2}{9b} + (1-p)\frac{(a_L - 2c + c_1)^2}{9b} < \frac{(a-c)^2}{9b},$$

which is satisfied if and only if $p < \frac{(a+a_L+c_1-3c)(a-c_1-a_L+c)}{(a_H-a_L)(a_H+a_L+2c_1-4c)} \equiv p^D$. On the other hand, the entrant enters after observing no expansion (off-the-equilibrium path) if and only if

$$\gamma\frac{(a_H - c)^2}{9b} + (1-\gamma)\frac{(a_L - c)^2}{9b} \geq \frac{(a-c)^2}{9b},$$

which holds if and only if $\gamma \geq \frac{(a-a_L)(a-2c+a_L)}{(a_H-a_L)(a_H+a_L-2c)} \equiv p^I$. Hence, the entrant stays out after observing expansion (in equilibrium), but enters after observing no expansion (out-of-equilibrium). As a consequence, the high-demand incumbent expands her business if and only if $\frac{(a_H-c_1)^2}{4b} - C_H \geq \frac{(a_H-c)^2}{4b}$, which implies $C_H \leq \frac{(a_H-c)^2}{4b} - \frac{(a_H-c_1)^2}{9b} \equiv B_H^{ED}$. Similarly for the low-demand incumbent, she expands if and only if $C_L \leq B_L^{ED}$. Hence, the strategy profile (Exp_H, Exp_L) for the incumbent and (Out_E, In_{NE}) for the entrant can be supported as a pooling PBE when $C_K \leq B_K^{ED}$ and entrant's beliefs are $\mu(H|E) = p < p^D$ and $\mu(H|NE) \geq p^I$; as described in Proposition 1 (part 3a).

- When $\mu(H|E) = p < p^D$ and $\mu(H|NE) < p^I$, the entrant stays out not only after observing expansion (in equilibrium), but also after observing no expansion (out-the-equilibrium). In this case, the high-demand incumbent expands her business if and only if $\frac{(a_H-c_1)^2}{4b} - C_H \geq \frac{(a_H-c)^2}{4b}$, which implies $C_H \leq \frac{(a_H-c_1)^2}{4b} - \frac{(a_H-c)^2}{4b} \equiv B_H^{CR}$. Similarly for the low-demand incumbent, she expands if and only if $C_L \leq B_L^{CR}$. Hence, the strategy profile (Exp_H, Exp_L) for the incumbent and (Out_E, Out_{NE}) for the entrant can be supported as a pooling PBE when $C_K \leq B_K^{CR}$ and entrant's beliefs are $\mu(H|E) = p < p^D$ and $\mu(H|NE) < p^I$; as described in Proposition 1 (part 3b).

- When $\mu(H|E) = p \geq p^D$ and $\mu(H|NE) < p^I$, the entrant enters after observing expansion (in equilibrium), but stays out after observing no expansion (out-the-equilibrium). In this case, the high-demand incumbent expands her business if and only if $\frac{(a_H - 2c_1 + c)^2}{9b} - C_H \geq \frac{(a_H - c)^2}{4b}$, which implies $C_H \leq \frac{(a_H - 2c_1 + c)^2}{9b} - \frac{(a_H - c)^2}{4b} \equiv B_H^E$. Similarly, the low-demand incumbent expands if and only if $C_L \leq B_L^E$. Hence, the strategy profile (Exp_H, Exp_L) for the incumbent and (In_E, Out_{NE}) for the entrant can be supported as a pooling PBE when $C_K \leq B_K^E$ and entrant's beliefs are $\mu(H|E) = p \geq p^D$ and $\mu(H|NE) < p^I$; as described in Proposition 3 (part 1).

- When $\mu(H|E) = p \geq p^D$ and $\mu(H|NE) \geq p^I$, the entrant enters not only after observing expansion (in equilibrium), but also after observing no expansion (out-the-equilibrium). In this case, the high-demand incumbent expands her business if and only if $\frac{(a_H - 2c_1 + c)^2}{9b} - C_H \geq \frac{(a_H - c)^2}{9b}$, which implies $C_H \leq \frac{(a_H - 2c_1 + c)^2}{9b} - \frac{(a_H - c)^2}{9b} \equiv \left(B_H^{ED} - B_H^{CR}\right) + B_H^E$, and similarly for the low-demand incumbent. Hence, the strategy profile (Exp_H, Exp_L) for the incumbent and (In_E, In_{NE}) for the entrant can be supported as a pooling PBE when $C_K \leq \left(B_K^{ED} - B_K^{CR}\right) + B_K^E$ and entrant's beliefs are $\mu(H|E) = p \geq p^D$ and $\mu(H|NE) \geq p^I$; as described in Proposition 3 (part 2). ■

6.3 *Proof of Lemma 2*

First, note that the separating equilibrium $(Exp_H, NoExp_L)$ with (In_E, Out_{NE}) survives the intuitive criterion, since there is no action from the incumbent that could be interpreted as an out-of-equilibrium action by the entrant, i.e., both expansion and no expansion are selected with an strictly positive probability by some type of incumbent. Because there are no out-of-equilibrium actions in the separating equilibrium, entrants do not sustain out-of-equilibrium beliefs that can be further restricted by the application of the Intuitive Criterion.

Let us start by checking if the pooling equilibria described in Proposition 1 (i.e., relatively low prior probability, $p < p^I$) survive the Intuitive Criterion:

- **Proposition 1, Part 2a:** Let us first check the pooling PBE $(NoExp_H, NoExp_L)$ with no entry when the entrant selects (In_E, Out_{NE}), given that $\mu(H|NE) = p < p^I$ and $\mu(H|E) \geq p^D$. If the high-demand incumbent deviates to Exp_H, the highest payoff she can obtain is $\frac{(a_H - c_1)^2}{4b} - C_H$, which strictly exceeds her equilibrium payoff of $\frac{(a_H - c)^2}{4b}$ if and only if $C_H < B_H^{CR}$. Similarly for the low-demand incumbent, who deviates to expansion if and only if $C_L < B_L^{CR}$. Given that the expansion costs supporting this PBE are $C_K > B_K^E$, the following cases can arise:
    - If $C_K \in (B_K^E, B_K^{CR})$ for both types of incumbents, then both incumbents would benefit by deviating to expansion, and the entrant's out-of-equilibrium beliefs become $\mu(H|E) = p < p^I$ (which induces the entrant to stay out, Out_E), Given that $\mu(H|NE) = p < p^I$, the entrant selects (Out_E, Out_{NE}), and incumbent K deviates to expansion since $\frac{(a_K - c_1)^2}{4b} - C_K > \frac{(a_K - c)^2}{4b}$, when $C_K < B_K^{CR}$. Given that $C_H \leq C_L$ and $B_L^{CR} < B_H^{CR}$, it follows that $C_K \in (B_K^E, B_L^{CR})$. Hence, when expansion costs satisfy $C_K \in (B_K^E, B_L^{CR})$, the pooling equilibrium $(NoExp_H, NoExp_L)$ with (In_E, Out_{NE}) violates the Intuitive Criterion.

– If $C_K > B_K^{CR}$ for both types of incumbents, then no incumbent deviates to expansion, and the entrant responds by using the prescribed strategy (In_E, Out_{NE}). Hence, when $C_K > B_K^{CR}$ the pooling $(NoExp_H, NoExp_L)$ with (In_E, Out_{NE}) survives the Intuitive Criterion.

– If $C_H \in (B_H^E, B_H^{CR})$ and $C_L > B_L^{CR}$, then only the high-demand incumbent deviates to expansion, and the entrant's out-of-equilibrium beliefs become $\mu(H|E) = 1$ (inducing him to enter, In_E), whereas his beliefs after observing no expansion are $\mu(H|NE) = p < p^I$ (inducing him to stay out, Out_{NE}). Thus, the high-demand incumbent does not expand since $\frac{(a_H - 2c_1 + c)^2}{9b} - C_H < \frac{(a_H - c)^2}{4b}$, given that $C_H > B_H^E$. The low-demand incumbent does not expand either since $\frac{(a_L - 2c_1 + c)^2}{9b} - C_L < \frac{(a_L - c)^2}{4b}$ given that $C_L > B_L^E$. Hence, when $C_H \in (B_H^E, B_H^{CR})$ and $C_L > B_L^{CR}$, the pooling equilibrium $(NoExp_H, NoExp_L)$ with (In_E, Out_{NE}) survives the Intuitive Criterion.

- **Proposition 1, Part 2b:** Let us now check if the pooling PBE $(NoExp_H, NoExp_L)$ with no entry survives the Intuitive Criterion when the entrant selects (Out_E, Out_{NE}), given that $\mu(H|NE) = p < p^I$ and $\mu(H|E) < p^D$. If the high-demand incumbent deviates to Exp_H, the highest payoff she can obtain is $\frac{(a_H - c_1)^2}{4b} - C_H$, which strictly exceeds her equilibrium payoff of $\frac{(a_H - c)^2}{4b}$ if and only if $C_H < B_H^{CR}$. This inequality violates the parameter conditions of this pooling equilibrium. Similarly for the low-demand incumbent. Hence, no type of incumbent deviates, and this pooling equilibrium survives the Intuitive Criterion.

- **Proposition 1, Part 3a:** Let us now check if the pooling PBE (Exp_H, Exp_L) with no entry survives the Intuitive Criterion when the entrant selects (Out_E, In_{NE}), given that $\mu(H|E) = p < p^D$ and $\mu(H|NE) \geq p^I$. If the high-demand incumbent deviates to $NoExp_H$, the highest payoff she can obtain from not expanding is $\frac{(a_H - c)^2}{4b}$, which strictly exceeds her equilibrium payoff from expansion of $\frac{(a_H - c_1)^2}{4b} - C_H$ if $C_H > B_H^{CR}$. Similarly, the low-demand incumbent deviates to no expansion if and only if $C_L > B_L^{CR}$. Given that the expansion costs supporting this PBE are $C_K \leq B_K^{ED}$ for both types of incumbents, the following cases can arise:

  – If $C_K \in (B_K^{CR}, B_K^{ED}]$ for both types of incumbents, then both incumbents deviate to no expansion, and the entrant's out-of-equilibrium beliefs become $\mu(H|NE) = p < p^D$ (which induces the entrant to stay out, Out_{NE}). Similarly, his beliefs after observing expansion are $\mu(H|E) = p < p^D$ (inducing him to stay out, Out_E).Then incumbent K deviates to no expansion if and only if $\frac{(a_K - c_1)^2}{4b} - C_K < \frac{(a_K - c)^2}{4b}$, which is true since $C_K \in (B_K^{CR}, B_K^{ED}]$. Given that $C_H \leq C_L$, $B_L^{CR} < B_H^{CR}$, and $B_L^{ED} < B_H^{ED}$, condition $C_K \in (B_K^{CR}, B_K^{ED}]$ can be more compactly expressed as $C_K \in (B_H^{CR}, B_L^{ED}]$. Hence, both types of incumbents deviate to no expansion in this case, and the pooling (Exp_H, Exp_L) with (Out_E, In_{NE}) violates the Intuitive Criterion.

  – If $C_K < B_K^{CR}$ for both types of incumbents, then no incumbent has incentives to deviate to no expansion, and the entrant responds by using the prescribed strategy (Out_E, In_{NE}). Hence, when $C_K < B_K^{CR}$ the pooling (Exp_H, Exp_L) survives the Intuitive Criterion.

– If $C_L \in (B_L^{CR}, B_L^{ED})$ and $C_H < B_H^{CR}$, then only the low-demand incumbent deviates to no expansion, and the entrant's out-of-equilibrium beliefs become $\mu(H|NE) = 0$ (inducing him to stay out, Out_{NE}). Similarly, his beliefs after observing expansion are $\mu(H|E) = p < p^D$ (inducing him to stay out, Out_E). Thus, the low-demand incumbent does not expand since $\frac{(a_L-c_1)^2}{4b} - C_L < \frac{(a_L-c)^2}{4b}$, when $C_L > B_L^{CR}$. In contrast, the high-demand incumbent expands since $\frac{(a_H-c_1)^2}{4b} - C_H > \frac{(a_H-c)^2}{4b}$ when $C_H < B_H^{CR}$. Hence, when expansion costs satisfy $C_L \in (B_L^{CR}, B_L^{ED})$ and $C_H < B_H^{CR}$ only the low-demand incumbent deviates to no expansion (whereas the high-demand incumbent still expands), and as a consequence the pooling equilibrium (Exp_H, Exp_L) with (Out_E, In_{NE}) violates the Intuitive Criterion.

- **Proposition 1, Part 3b:** Let us now check the pooling PBE (Exp_H, Exp_L) with no entry survives the Intuitive Criterion when the entrant selects (Out_E, Out_{NE}), given that $\mu(H|E) = p < p^D$ and $\mu(H|NE) < p^I$. First, the highest payoff that the high-demand incumbent can obtain by deviating to no expansion is $\frac{(a_H-c)^2}{4b}$, which strictly exceeds her equilibrium payoff of $\frac{(a_H-c_1)^2}{4b} - C_H$ if and only if $C_H > B_H^{CR}$. This inequality violates the parameter conditions supporting this PBE. Similarly for the low-demand incumbent. Hence, no type of incumbent deviates to no expansion in this case, and this pooling PBE survives the Intuitive Criterion.

Let us continue by checking the pooling equilibria described in Proposition 2 (i.e., intermediate prior probability, $p^I \leq p < p^D$):

- **Proposition 2, Part 1:** Let us check if the pooling PBE $(NoExp_H, NoExp_L)$ with entry survives the Intuitive Criterion when the entrant selects (Out_E, In_{NE}), given that $\mu(H|NE) = p \geq p^I$ and $\mu(H|E) < p^D$. If the high-demand incumbent deviates to expansion, the highest payoff that she can obtain is $\frac{(a_H-c_1)^2}{4b} - C_H$, which strictly exceeds her equilibrium payoff of $\frac{(a_H-c)^2}{9b}$ if and only if $C_H < B_H^{ED}$. This inequality contradicts the parameter conditions supporting this pooling PBE. Similarly for the low-demand incumbent. Hence, no type of incumbent deviates, and this pooling equilibrium in this case survives the Intuitive Criterion.

- **Proposition 2, Part 2:** Let us now check if the pooling PBE $(NoExp_H, NoExp_L)$ with entry survives the Intuitive Criterion when the entrant selects (In_E, In_{NE}), given that $\mu(H|NE) = p \geq p^I$ and $\mu(H|E) \geq p^D$. If the high-demand incumbent deviates to expansion, the highest payoff that she can obtain is $\frac{(a_H-c_1)^2}{4b} - C_H$, which strictly exceeds her equilibrium payoff of $\frac{(a_H-c)^2}{9b}$ if and only if $C_H < B_H^{ED}$. Similarly, the low-demand incumbent deviates to expansion if and only if $C_L < B_L^{ED}$. Given that the expansion costs supporting this PBE are $C_K > B_K^O$, where $B_K^O \equiv (B_K^{ED} - B_K^{CR}) + B_K^E$ for both types of incumbents, the following cases can arise:

  – If $C_K \in (B_K^O, B_K^{ED})$ for both types of incumbents, then both incumbents deviate to expansion, and the entrant's out-of-equilibrium beliefs become $\mu(H|E) = p \geq p^I$ (but $p < p^D$, which induces the entrant to play Out_E), whereas his beliefs after observing no expansion are

$\mu(H|NE) = p \geq p^I$ (which induces him to enter, In_{NE}). Then incumbent K deviates to expansion if and only if $\frac{(a_K - c_1)^2}{4b} - C_K > \frac{(a_K - c)^2}{9b}$, which is true since $C_K \in (B_K^O, B_K^{ED})$. Moreover, given that $C_H \leq C_L$ and $B_L^{ED} < B_H^{ED}$, condition $C_K \in (B_K^O, B_K^{ED})$ can be more compactly expressed as $C_K \in (B_K^O, B_L^{ED}]$. Hence, both types of incumbents deviate to expansion, and the pooling $(NoExp_H, NoExp_L)$ with (In_E, In_{NE}) violates the Intuitive Criterion.

– If $C_K > B_K^{ED}$ for both types of incumbents, then no incumbent has incentives to deviate to expansion, and the entrant responds by using the prescribed strategy (In_E, In_{NE}). Hence, when $C_K > B_K^{ED}$ the pooling $(NoExp_H, NoExp_L)$ survives the Intuitive Criterion.

– If $C_H \in (B_H^O, B_H^{ED})$ and $C_L < B_L^{ED}$, then only the high-demand incumbent deviates to expansion, and the entrant's out-of-equilibrium beliefs become $\mu(H|E) = 1$ (inducing him to enter, In_E), whereas his beliefs after observing no expansion are $\mu(H|NE) = p \geq p^I$ (inducing him to enter, In_{NE}). Thus, the high-demand incumbent does not expand since $\frac{(a_H - 2c_1 + c)^2}{9b} - C_H < \frac{(a_H - c)^2}{9b}$, given that $C_H > B_H^O$. Similarly, the low-demand incumbent does not expand since $C_L > B_L^O$ at this pooling equilibrium. Hence, when $C_H \in (B_H^O, B_H^{ED})$ and $C_L < B_L^{ED}$ no type of incumbent expands, and the pooling equillibrium $(NoExp_H, NoExp_L)$ survives the Intuitive Criterion.

Let us finally check the pooling equilibria described in Proposition 3 (i.e., relatively high prior probability, $p^D \leq p$):

- **Proposition 3, Part 1:** Let us first check if the pooling PBE (Exp_H, Exp_L) with entry survives the Intuitive Criterion when the entrant selects (In_E, Out_{NE}), given that $\mu(H|E) = p \geq p^D$ and $\mu(H|NE) < p^I$. First, the highest payoff that the high-demand incumbent can obtain by deviating to no expansion is $\frac{(a_H - c)^2}{4b}$, which strictly exceeds her equilibrium payoff of $\frac{(a_H - 2c_1 + c)^2}{9b} - C_H$ if and only if $C_H > B_H^E$. The last inequality contradicts the parameter conditions supporting this PBE (i.e., $C_H \leq B_H^E$). Similarly for the low-demand incumbent. Hence, no type of incumbent deviates, and this pooling PBE survives the Intuitive Criterion.

- **Proposition 3, Part 2:** Let us now check if the pooling PBE (Exp_H, Exp_L) with entry survives the Intuitive Criterion when the entrant selects (In_E, In_{NE}), given that $\mu(H|E) = p \geq p^D$ and $\mu(H|NE) \geq p^I$. First, note that the highest payoff that the high-demand incumbent can obtain by deviating to no expansion is $\frac{(a_H - c)^2}{4b}$, which strictly exceeds her equilibrium payoff of $\frac{(a_H - 2c_1 + c)^2}{9b} - C_H$ if and only if $B_H^E < C_H$. Similarly, the low-demand incumbent deviates to no expansion if and only if $B_L^E < C_L$. Given that the expansion costs supporting this PBE satisfy $C_K \leq B_K^O$ for both types of incumbents, the following cases can arise:

  – If $C_K \in (B_K^E, B_K^O]$ for both types of incumbents, then both incumbents deviate to no expansion, and the entrant's out-of-equilibrium beliefs become $\mu(H|NE) = p \geq p^D$ (which induces the entrant to play In_{NE}), whereas his beliefs after observing expansion are $\mu(H|E) = p \geq p^D$

(which induces him to enter, In_E). Then incumbent K deviates to no expansion if and only if $\frac{(a_K-2c_1+c)^2}{9b} - C_K < \frac{(a_K-c)^2}{9b}$, given that $C_K > B_K^O$. The last inequality cannot hold since $C_K \in (B_K^E, B_K^O]$. Hence, no type of incumbent deviates to no expansion, and the pooling equilibrium (Exp_H, Exp_L) with (In_E, In_{NE}) survives the Intuitive Criterion.

- If $C_K < B_K^E$ for both types of incumbents, then no incumbent deviates to expansion, and the entrant responds by using the prescribed strategy (In_E, In_{NE}). Hence, when $C_K < B_K^E$, the pooling (Exp_H, Exp_L) with (In_E, In_{NE}) survives the Intuitive Criterion.

- If $C_L \in (B_L^E, B_L^O]$ but $C_H < B_H^E$, then the high-demand incumbent does not deviate to no expansion, while the low-demand incumbent does deviate. The entrant's out-of-equilibrium beliefs become $\mu(H|NE) = 0$, whereas his beliefs after observing expansion are $\mu(H|E) = p \geq p^D$, inducing the entrant to choose (In_E, Out_{NE}). On the one hand, the high-demand incumbent expands since $\frac{(a_H-2c_1+c)^2}{9b} - C_H > \frac{(a_H-c)^2}{4b}$, given that $C_H < B_H^E$. On the other hand, the low-demand incumbent does not expand since $\frac{(a_L-2c_1+c)^2}{9b} - C_L < \frac{(a_L-c)^2}{4b}$ given that $C_L > B_L^E$. Hence, when $C_L \in (B_L^E, B_L^O]$ and $C_H < B_H^E$, the pooling equilibrium (Exp_H, Exp_L) with (In_E, In_{NE}) violates the Intuitive Criterion.

- If $C_H \in (B_H^E, B_H^O]$ but $C_L < B_L^E$, then the low-demand incumbent does not deviate to no expansion, while the high-demand incumbent does deviate. The entrant's beliefs out-of-equilibrium become $\mu(H|NE) = 1$, whereas his beliefs after observing expansion are $\mu(H|E) = p \geq p^D$, which induces the entrant to choose (In_E, In_{NE}). Therefore, the high-demand incumbent expands since $\frac{(a_H-2c_1+c)^2}{9b} - C_H > \frac{(a_H-c)^2}{9b}$, given that $C_H < B_H^O$. Similarly, the low-demand incumbent expands since $\frac{(a_L-2c_1+c)^2}{4b} - C_L > \frac{(a_L-c)^2}{4b}$ given that $C_L < B_L^E < B_L^O$. Hence, when $C_H \in (B_H^E, B_H^O]$ and $C_L < B_L^E$, the pooling equilibrium (Exp_H, Exp_L) with (In_E, In_{NE}) survives the Intuitive Criterion. ■

6.4 *Semi-separating equilibria (Propositions 4, 5, and 6)*

In the expansion signaling game in which expansion reduces the incumbent's costs, the following strategy profiles can be supported as semi-separating PBE of the game:

(i) *If* $p < p^D$,

(a) *When demand is high, the incumbent expands her business,* $q_H = 1$, *and when demand is low, the incumbent expands with probability* $q_L \in (0, 1)$,

$$q_L = \frac{p}{1-p}\frac{1-p^D}{p^D} \tag{7}$$

(b) *After observing expansion, the entrant enters with probability* $r = \frac{B_L^{CR}-C_L}{B_L^{CR}-B_L^E}$; *and after observing no expansion, the entrant does not enter,* $s = 0$, *and his beliefs are* $\mu(H|E) = p^D$ *and* $\mu(H|NE) = 0$. *This equilibrium can only be supported if* $C_H < B_L^{CR}$ *and*

$\max\left\{B_L^E, C_L^2, C_H\right\} < C_L < B_L^{CR}$, *where*

$$C_L^2 = B_L^{CR} - B_H^{CR}F + FC_H,\ \ F = \frac{B_L^{CR} - B_L^E}{B_H^{CR} - B_H^E} \tag{8}$$

(ii) *If* $p^I \leq p < p^D$*:*

(a) *The incumbent expands with probabilities* $q_H \in (0,1)$ *and* $q_L \in (0,1)$ *when market demand is high and low, respectively.*

$$q_H = \frac{p^D(p - p^I)}{p(p^D - p^I)},\ \ \textit{and}\ \ q_L = \frac{(1-p^D)(p-p^I)}{(1-p)(p^D - p^I)} \tag{9}$$

(b) *After observing expansion, the entrant enters with probability*

$$r = \frac{B_L^{CR} - C_L}{B_L^{CR} - B_L^E} + \frac{B_L^{ED} - B_L^{CR}}{B_L^{CR} - B_L^E}\frac{C_L^2 - C_L}{C_L^2 - C_L^1} \tag{10}$$

After observing no expansion, the entrant enters with probability $s = \frac{C_L^2 - C_L}{C_L^2 - C_L^1}$ *where* $C_L^1 = B_L^{ED} - FB_H^{ED} + FC_H$ *and* C_L^2 *was defined in part (i). The entrant's beliefs are* $\mu\left(H|E\right) = p^D$ *and* $\mu\left(H|NE\right) = p^I$*. This equilibrium can be supported if*

$$\max\left\{C_H, C_L^1, C_L^3\right\} < C_L < C_L^2 \textit{ and } B_H^E < C_H < \frac{B_L^{CR} - FB_H^{CR}}{1-F}, \tag{11}$$

where $C_H^3 = \frac{C_L^2\left(B_L^{ED} - B_L^{CR} + B_L^E\right) - C_L^1 B_L^E}{F\left(B_H^{ED} - B_H^{CR}\right)}$.

(iii) *If* $p^D \leq p$*, there are no semi-separating PBE.*

(iv) *There are no other semi-separating equilibria other than those characterized in parts (i) and (ii).*

Proof. *(i).* When $q_H = 1$ and $q_L \in (0,1)$, the entrant's beliefs after observing no expansion are $\gamma = \mu\left(H|NE\right) = 0$, which leads him to stay out of the market because $\frac{(a_L - c)^2}{9b} < \frac{(a-c)^2}{9b}$. In case that the entrant observes expansion, he mixes if his beliefs $\mu = \mu\left(H|E\right)$ are such that

$$\mu\frac{(a_H - 2c + c_1)^2}{9b} + (1-\mu)\frac{(a_L - 2c + c_1)^2}{9b} = \frac{(a-c)^2}{9b},$$

where $\mu = \mu\left(H|E\right) = \frac{p}{p + (1-p)q_L}$. Solving for q_L we obtain

$$q_L = \frac{p}{1-p}\frac{\left[(a_H - a) - (c - c_1)\right]}{\left[(a - a_L) + (c - c_1)\right]}\frac{a + a_H - 3c + c_1}{a + a_L - 3c + c_1} \equiv \frac{p}{1-p}\frac{1-p^D}{p^D},$$

where $q_L \in (0,1)$ only if $p < p^D$. Regarding the incumbent, when demand is low, the incumbent mixes if and only if

$$r\frac{(a_L - 2c_1 + c)^2}{9b} + (1-r)\frac{(a_L - c_1)^2}{4b} - C_L = \frac{(a_L - c)^2}{4b}.$$

Solving for r, $r = \frac{B_L^{CR} - C_L}{B_L^{CR} - B_L^E}$. Note that $r > 0$ only if $C_L < B_L^{CR}$, and $r < 1$ if $C_L > B_L^E$. On the other hand, when demand is high, she expands if and only if

$$r\frac{(a_H - 2c_1 + c)^2}{9b} + (1-r)\frac{(a_H - c_1)^2}{4b} - C_H > \frac{(a_H - c)^2}{4b},$$

which implies $B_H^{CR} - \frac{B_L^{CR}}{F} + \frac{C_L}{F} > C_H$. That is, $C_L > C_L^2$ where $C_L^2 \equiv B_L^{CR} - B_H^{CR}F + FC_H$, where $C_L^2 > 0$ for any $C_H \geq 0$. Because C_L must satisfy $C_L > C_L^2$, $C_L > C_H$, and $C_L > B_L^E$, then $B_L^{CR} > C_L > \max\left\{B_L^E, C_L^2, C_H\right\}$. Note that when $C_H = B_H^E$ then $C_L^2 = B_L^E$. If $B_H^E > B_L^E$, $\max\left\{B_L^E, C_L^2, C_H\right\}$ reduces to $\max\left\{B_L^E, C_H\right\}$ as the constraint $C_L > C_H$ is more binding than $C_L > C_L^2$, thus reducing to Case 1 of Figure 4 in the text. If $B_H^E < B_L^E$, Case 2 of Figure 4 applies and either C_L^2 or C_H may become the lower binding constraint on C_L, contingent upon the value of C_H. As $C_H < C_L$, the upper bound on C_H is B_L^{CR}, given that $C_L < B_L^{CR}$.

(ii) Next we investigate whether there exists an equilibrium with both types of incumbent randomizing. In this case, after observing an expansion, the entrant enters if his beliefs $\mu = \mu(H|E)$ are such that

$$\mu\frac{(a_H - 2c + c_1)^2}{9b} + (1-\mu)\frac{(a_L - 2c + c_1)^2}{9b} = \frac{(a - c)^2}{9b},$$

where $\mu = \mu(H|E) = \frac{pq_H}{pq_H + (1-p)q_L}$. On the other hand, when the entrant observes no expansion, then he mixes if and only if his beliefs $\gamma = \mu(H|NE)$ are such that

$$\gamma\frac{(a_H - c)^2}{9b} + (1-\gamma)\frac{(a_L - c)^2}{9b} = \frac{(a - c)^2}{9b},$$

where $\gamma = \mu(H|NE) = \frac{p(1-q_H)}{p(1-q_H) + (1-p)(1-q_L)}$. Solving now simultaneously for q_H and q_L we obtain $q_H = \frac{p^D(p-p^I)}{p(p^D-p^I)}$ and $q_L = \frac{(1-p^D)(p-p^I)}{(1-p)(p^D-p^I)}$. Substituting q_H and q_L in $\mu(H|E)$ and $\mu(H|NE)$ we obtain $\mu(H|E) = p^D$ and $\mu(H|NE) = p^I$. The solution yields proper probabilities q_H and q_L if $p^I < p < p^D$, in which case $q_H > q_L$.

Note that $q_H > q_L$ implies $\frac{1-p^D}{1-p} < \frac{p^D}{p}$. That is, $p^I < p < p^D$.

Regarding the incumbent, when demand is high, she mixes if and only if

$$r\frac{(a_H - 2c_1 + c)^2}{9b} + (1-r)\frac{(a_H - c_1)^2}{4b} - C_H = s\frac{(a_H - c)^2}{9b} + (1-s)\frac{(a_H - c)^2}{4b}.$$

On the other hand, when demand is low, the incumbent mixes if and only if

$$r\frac{(a_L - 2c_1 + c)^2}{9b} + (1-r)\frac{(a_L - c_1)^2}{4b} - C_L = s\frac{(a_L - c)^2}{9b} + (1-s)\frac{(a_L - c)^2}{4b}.$$

Solving simultaneously for r and s, we obtain $s = \frac{C_L^2 - C_L}{C_L^2 - C_L^1}$ and

$$r = \frac{B_L^{CR} - C_L}{B_L^{CR} - B_L^E} + \frac{B_L^{ED} - B_L^{CR}}{B_L^{CR} - B_L^E} \frac{C_L^2 - C_L}{C_L^2 - C_L^1},$$

where $C_L^1 \equiv B_L^{ED} - FB_H^{ED} + FC_H$, and C_L^2 was defined in part (i). The solution for r and s yields proper probabilities if (a) either $C_L^1 < C_L < C_L^2$ or $C_L^2 < C_L < C_L^1$, and (b) $C_L^3 < C_L < C_L^4$, where

$$C_L^3 \equiv \frac{C_L^2 \left[B_L^{ED} - B_L^{CR} + B_L^E\right] - C_L^1 B_L^E}{F\left(B_H^{ED} - B_H^{CR}\right)} \text{ and } C_L^4 \equiv \frac{C_L^2 B_L^{ED} - C_L^1 B_L^{CR}}{F\left(B_H^{ED} - B_H^{CR}\right)}.$$

It can be shown that (a) and (b) yield an empty set if $C_L^1 > C_L^2$, hence we restrict attention to the case that $C_L^2 > C_L^1$, which is valid if $c - c_1 < \frac{2}{7}\frac{(a_H - c)(a_L - c)}{(a_H + a_L - 2c)}$. Combining (a) and (b) with the requirement that $C_L > C_H$ yields the following region for C_L,

$$\max\left\{C_H, C_L^1, C_L^3\right\} < C_L < C_L^2.$$

As $C_L^4 > C_L^2$ then the upper bound on C_L becomes, therefore, C_L^2. The region for C_L is non-empty if $C_H < C_L^2$ which yields the upper bound on C_H (i.e., $C_H < \frac{B_L^{CR} - FB_H^{CR}}{1-F}$). In addition, in order for $C_L^3 < C_L^2$ to be satisfied, it is necessary that $C_H > B_H^E$ (note that when $C_H = B_H^E$, $C_L^2 = B_L^E$, and $C_L^3 < C_L^2$ only if $C_L^2 > B_L^E$, which imposes the lower bound B_H^E on C_H). Hence, the range of C_L is nonempty for

$$B_H^E < C_H < \frac{B_L^{CR} - FB_H^{CR}}{1-F}.$$

(iii) Next, we investigate whether there exists an equilibrium with $q_L = 1$ and $q_H < 1$. In this case, the entrant's posterior beliefs are $\gamma = \mu(H|NE) = 1$ after observing no expansion, which leads him to enter because $\frac{(a_H - c)^2}{9b} > \frac{(a-c)^2}{9b}$. In the case that the entrant observes a expansion from the incumbent, then the entrant mixes with probability $s \in (0,1)$ if and only if his beliefs $\mu = \mu(H|E)$ are such that

$$\mu\frac{(a_H - 2c + c_1)^2}{9b} + (1-\mu)\frac{(a_L - 2c + c_1)^2}{9b} = \frac{(a-c)^2}{9b},$$

where $\mu = \mu(H|E) = \frac{pq_H}{pq_H + (1-p)}$. Solving for q_H in the above expression, we obtain

$$q_H = \frac{1-p}{p}\frac{[(a_L - a) - (c - c_1)]}{[(a - a_H) + (c - c_1)]}\frac{a + a_L - 3c + c_1}{a + a_H - 3c + c_1} \equiv \frac{1-p}{p}\frac{p^D}{1-p^D},$$

where $q_H \in (0,1)$ only if $p > p^D$. Regarding the incumbent, when demand is high, she mixes if and only if

$$r\frac{(a_H - 2c_1 + c)^2}{9b} + (1-r)\frac{(a_H - c_1)^2}{4b} - C_H = \frac{(a_H - c)^2}{9b},$$

(where r is the probability with which the entrant enters the market after observing an expansion). Solving for r, we have $r = \frac{B_H^{ED} - C_H}{B_H^{CR} - B_H^E}$. Note that $r > 0$ only if $C_H < B_H^{ED}$, and $r < 1$ for all $C_H > B_H^{ED} + B_H^E - B_H^{CR}$.

On the other hand, when demand is low, the incumbent decides to expand if

$$r\frac{(a_L - 2c_1 + c)^2}{9b} + (1-r)\frac{(a_L - c_1)^2}{4b} - C_L > \frac{(a_L - c)^2}{9b},$$

and solving for C_L, we obtain $C_L \leq C_L^1$ where $C_L^1 = B_L^{ED} - B_H^{ED}F + C_H F$, where $C_L^1 > 0$, for any $C_H \geq 0$. Hence, $C_H < C_L < C_L^1$. Note that $C_H < C_L^1$ implies $C_H < \frac{B_L^{ED} - FB_H^{ED}}{1-F} \equiv C_H^{**}$. In figure A1 we depict the region implied by the constraint $C_H < C_L < C_L^1$. The boundaries of this region can be specified as follows,

Region A1 (shaded area): $0 < C_H < C_H^{**}$, and $C_H < C_L < C_L^1$

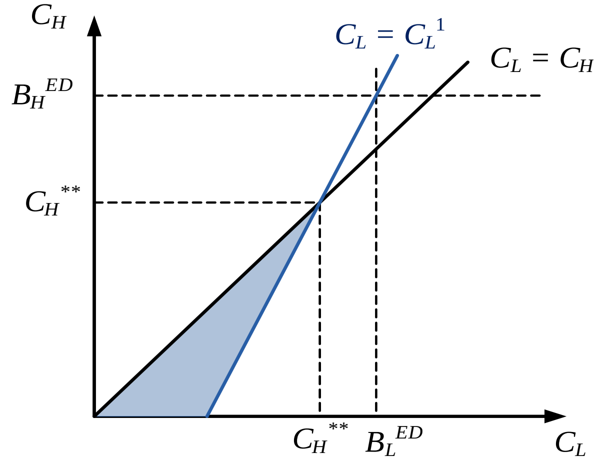

Figure A1: Feasible region with $q_L = 1$ and $q_H < 1$.

Combining Region A1 with the requirement that $C_H > B_H^{ED} + B_H^E - B_H^{CR}$ leads to a contradiction because $B_H^{ED} + B_H^E - B_H^{CR} > C_H^{**}$. Hence, there does not exist an equilibrium with $q_L = 1$ and $q_H < 1$.

The other types of semi-separating equilibria considered in parts (i) and (ii) require that $p < p^D$. Thus, there are no semi-separating PBE with positive probabilities of expansion by both firms is $p > p^D$.

(iv) We now check that other semi-separating strategy profiles with zero probabilities cannot be supported in equilibrium. Let us first check $q_H = 0$ and $q_L \in (0,1)$. In this case, the entrant's posterior beliefs are $\mu(H|E) = 0$ after observing a expansion, which leads him to do not enter because $\frac{(a_L - 2c + c_1)^2}{9b} < \frac{(a-c)^2}{9b}$. In the case that the entrant observes no expansion from the incumbent, the entrant mixes if and only if his beliefs $\gamma = \mu(H|NE)$ are such that

$$\gamma\frac{(a_H - c)^2}{9b} + (1-\gamma)\frac{(a_L - c)^2}{9b} = \frac{(a-c)^2}{9b}$$

where $\gamma = \mu(H|NE) = \frac{p}{p+(1-p)(1-q_L)}$. Solving for q_L in the above expression, we obtain $q_L = \frac{p-R_4}{(p-1)R_4}$, where $R_4 = \frac{(c-c_1+a-a_L)(a-c+a_L-c_1)}{(a_H-a_L)(a_H+a_L-2c)}$. But note that $q_L > 1$ if $p - R_4 > pR_4 - R_4$, which is valid if $R_4 < 1$. Indeed, $R_4 < 1$ by our assumption that $a_H > a + c - c_1$. Hence, the above semi-separating strategy profile cannot be supported as an equilibrium.

Let us now check $q_H \in (0,1)$ and $q_L = 0$. In this case, the entrant's posterior beliefs are $\mu(H|E) = 1$ after observing a expansion, which leads him to enter because $\frac{(a_H-2c+c_1)^2}{9b} > \frac{(a-c)^2}{9b}$. In the case that the entrant observes no expansion from the incumbent, then the entrant mixes if and only if his beliefs $\gamma = \mu(H|NE)$ are such that

$$\gamma\frac{(a_H-c)^2}{9b} + (1-\gamma)\frac{(a_L-c)^2}{9b} = \frac{(a-c)^2}{9b},$$

where $\gamma = \mu(H|NE) = \frac{p(1-q_H)}{p(1-q_H)+(1-p)}$. Solving for q_H in the above expression, we obtain $q_H = \frac{a(a-2c)+2pca_H-pa_H^2+(1-p)(2c-a_L)a_L}{p(a-a_H)(a+a_H)-2c}$. However, $q_H > 1$ for all $a_L > 2c - c_1$ (active entrant, which is true by assumption). Therefore, this semi-separating strategy profile cannot be supported as well.

Comparative statics

First, in the semi-separating equilibrium where $q_H = 1$ and $q_L \in (0,1)$ (Type 1) we have that $\frac{\partial q_L}{\partial p} > 0$ for all parameter values, which implies $\frac{\partial(q_H-q_L)}{\partial p} < 0$. Second, in the semi-separating equilibrium where both incumbents randomize (Type 2), we have

$$q_H - q_L = \frac{p-p^D}{p^D-p^I}\left[\frac{p^D}{p} - \frac{1-p^D}{1-p}\right],$$

which approaches zero when $p \to p^D$, but is strictly positive when $p \to p^I$. Furthermore,

$$\left.\frac{\partial(q_H-q_L)}{\partial p}\right|_{p\to p^I} = \frac{1}{p^D-p^I}\left[\frac{p^D}{p^I} - \frac{1-p^D}{1-p^I}\right] > 0, \quad \text{and}$$

$$\left.\frac{\partial(q_H-q_L)}{\partial p}\right|_{p\to p^D} = \frac{1}{p^D-p^I}\left[\frac{p^I}{p^D} - \frac{1-p^I}{1-p^D}\right] < 0,$$

which implies that the difference $q_H - q_L$ starts at a positive value when $p \to p^I$, increases in p, then decreases in p, and finally approaches zero when $p \to p^D$. ■

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